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TNT EQUIVALENCY OF M10 PROPELLANT

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MARCH 1978

US ARMY ARMAMENT RESEARCH AND DEVELOPMENT COMMAND
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Peak, side-on blast overpressure and scaled, positive impulse have been measured for M10 single-perforated propellant, web size 0.018 inches, using configurations that simulate the handling of bulk material during processing and shipment. Quantities of 11.34, 22.7, 45.4, and 65.8 kg were tested in orthorhombic shipping containers and fiberboard boxes. High explosive equivalency values for each test series were obtained as a function of scaled distance by comparison

20. ABSTRACT (Continued)

to known pressure, arrival time and impulse characteristics for hemispherical TNT surface bursts. The equivalencies were found to depend significantly on scaled distance, with higher values of 150-100 percent (pressure) and 350-125 percent (positive impulse) for the extremes within the range from 1.19 to 3.57 $m/kg^{1/3}$. Equivalencies as low as 60-140 percent (pressure) and 30-75 percent (positive impulse) were obtained in the range of 7.14 to 15.8 $m/kg^{1/3}$. Within experimental error, both peak pressure and positive impulse scaled as a function of charge weight for all quantities tested in the orthorhombic configuration.

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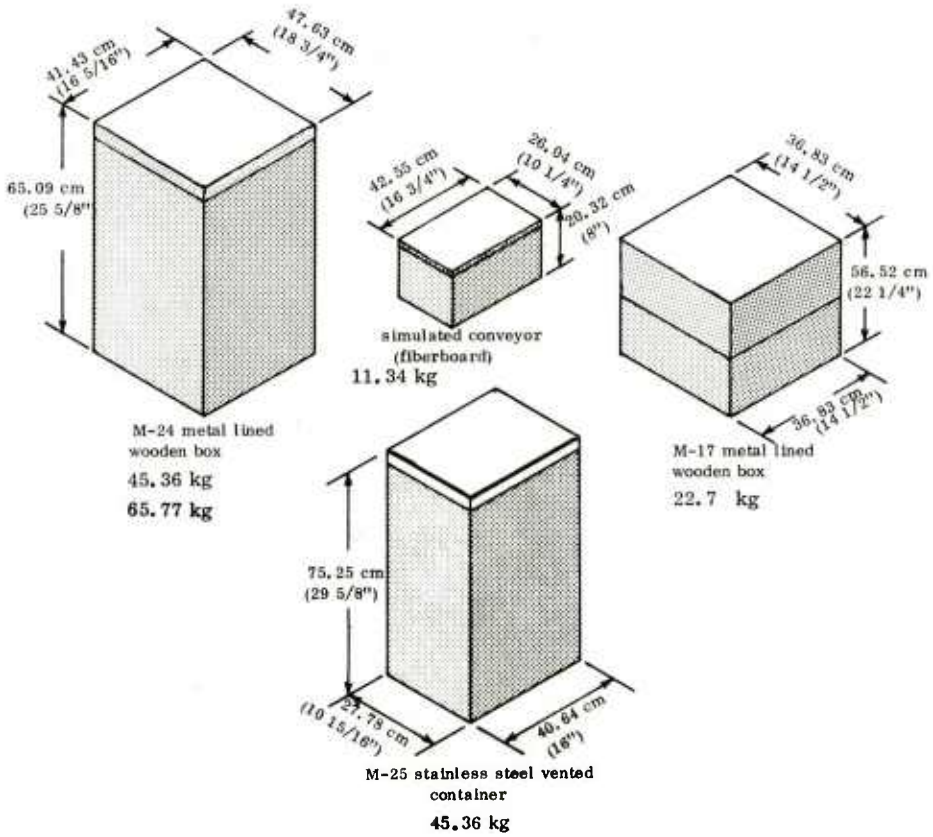
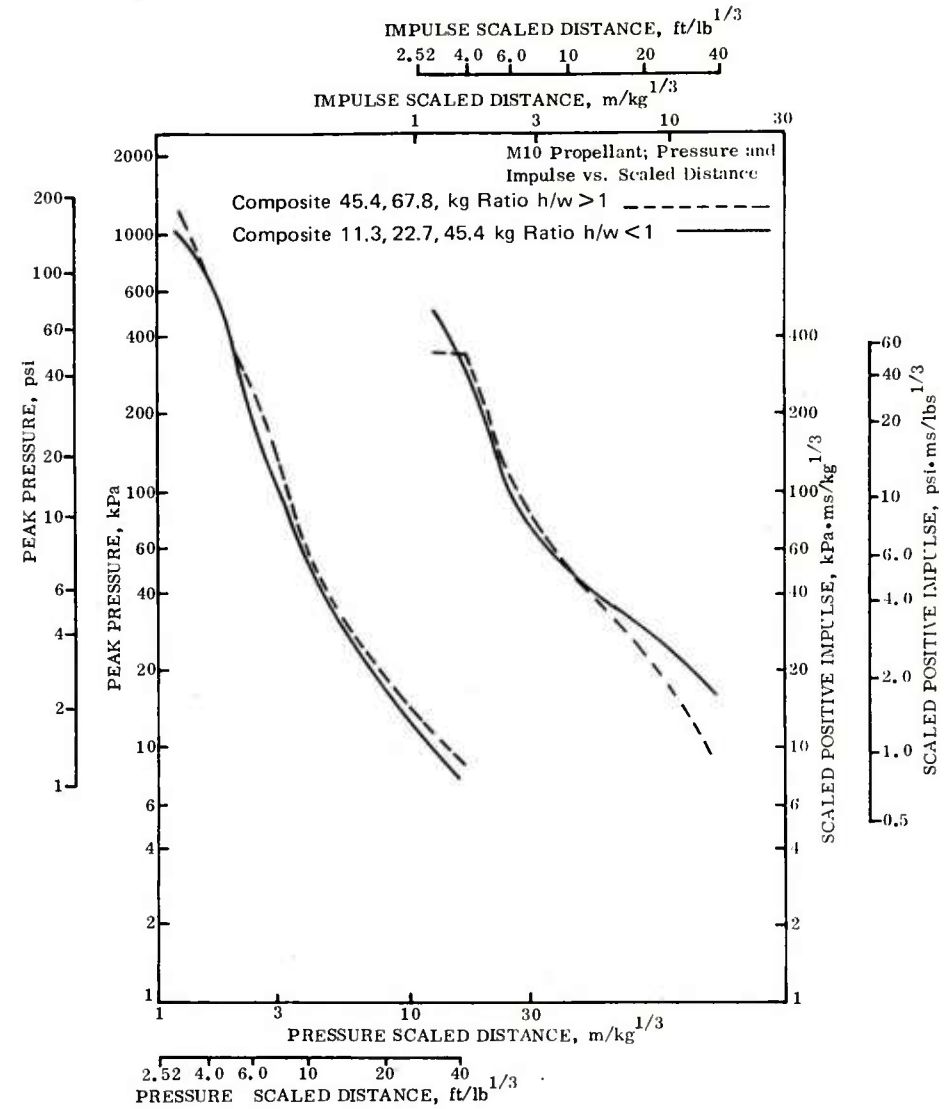
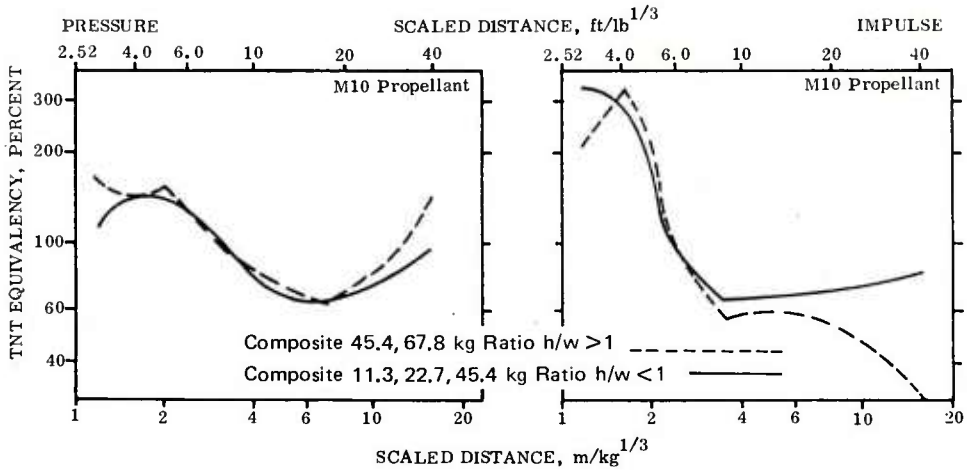
SUMMARY

M10 propellant, 0.018 inch web, single perforation, was detonated in configurations representative of orthorhombic shipping boxes, and a simulated in-plant conveyor bucket. Blast output parameters were measured and TNT equivalency was computed based on comparison with TNT hemispherical surface bursts. The results of these tests are represented in the table below and in figures on the following pages. Within experimental error, the pressures and impulses from the orthorhombic and conveyor bucket configurations (11.34 kg, 22.68 kg, 45.36 kg, 65.77 kg) scaled according to the cube root of charge weight.

Configuration Mass	Pressure (P) and Impulse (I) TNT Equivalency (%) at Scaled Distance											
	$1.19 m/kg^{1/3}$ ($3.0 ft/lb^{1/3}$)		$1.61 m/kg^{1/3}$ ($4.05 ft/lb^{1/3}$)		$2.13 m/kg^{1/3}$ ($5.38 ft/lb^{1/3}$)		$3.57 m/kg^{1/3}$ $9.0 ft/lb^{1/3}$)		$7.14 m/kg^{1/3}$ ($18.0 ft/lb^{1/3}$)		$15.9 m/kg^{1/3}$ ($40 ft/lb^{1/3}$,	
	P	I	P	I	P	I	P	I	P	I	P	I
Ratio h/w < 1 11.34 kg 22.7 kg 45.36 kg	115	330	145	280	140	130	90	65	60	70	90	75
Ratio h/w > 1 45.36 kg 65.77 kg	165	210	140	330	150	165	90	80	75	60	140	30




IMPULSE SCALED DISTANCE, ft/lb^1/3
2.52 4.0 6.0 10 20 40
IMPULSE SCALED DISTANCE, m/kg^1/3
1 3 10 30
M10 Propellant; Pressure and Impulse vs. Scaled Distance
Composite 45.4, 67.8, kg Ratio h/w > 1
Composite 11.3, 22.7, 45.4 kg Ratio h/w < 1
PEAK PRESSURE, psi
PEAK PRESSURE, kPa
SCALED POSITIVE IMPULSE, kPa•ms/kg^1/3
SCALED POSITIVE IMPULSE, psi•ms/lbs^1/3
PRESSURE SCALED DISTANCE, m/kg^1/3
PRESSURE SCALED DISTANCE, ft/lb^1/3


PRESSURE
SCALED DISTANCE, ft/lb^1/3
IMPULSE
M10 Propellant
M10 Propellant
TNT EQUIVALENCY, PERCENT
Composite 45.4, 67.8 kg Ratio h/w > 1
Composite 11.3, 22.7, 45.4 kg Ratio h/w < 1
SCALED DISTANCE, m/kg^1/3

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INTRODUCTION

BACKGROUND

Plans are currently underway for designing new and modernizing existing U.S. Army Production facilities where M10 propellant is loaded into munitions. Although all building and equipment designs have not been finalized, it is known that bulk quantities of this material will be found at various points in the load, assemble and pack (LAP) operations.

M10 propellant is a Class 7 (DOT Class B) material and is shipped in four types of containers, the type being dictated by the weight of the propellant to be shipped. For a quantity of 22.7 kg the required container is a M-17 metal lined wood box, Drawing Number 76-4-56. For quantities of 45.4 kg two types of containers, a M-24 metal lined wood box, Drawing Number 76-4-46 and a M-25 stainless steel vented container, Drawing Number 7549033 are used. The M-24 metal lined wood box is also used for quantities of 68.0 kg. The various shipping containers of M10 propellant will be received and stored in Stradley Igloos. The bulk material will then be weighed into 11.34 kg increments and transferred via bucket conveyor to the propellant charge preparation building.

Safety engineering and cost effectiveness considerations require knowledge of hazardous material characteristics as an input to facility design requirements. In this instance, specific data is required on the explosive output characteristics of M10 propellant in quantities and configurations representative of those found in processing.

OBJECTIVE

The objective of this work was to determine the maximum output from the detonation of M10 propellant in terms of the airblast overpressure and positive impulse compared to known characteristics of a hemispherical surface blast of TNT.

MATERIAL

The test material was Propellant, Explosive, Solid Class B Propellant M10, Type 2 (Lot numbers RAD 68725 and RAD 88725), 0.018 inch web, single perforation (SP) grain, containing 98 percent nitrocellulose (13.25 percent N), 1 percent potassium sulfate and 1 percent diphenylamine. The propellant was received from Radford Army Ammunition Plant in standard shipping boxes (Drawing Number 76-4-46) containing 65.8 kg net mass.

TEST PLAN

Airblast output was evaluated for masses and configurations of M10 propellant representative of three shipping and in-plant situations. Physical characteristics of the test items were as follows:

(1) An orthorhombic container, Figure 1(a), was used to simulate the conveyor bucket. Two-piece telescoping fiberboard boxes were fabricated and filled with 11.34 kg of M10 propellant.

(2) M-17 metal-lined wood boxes, Figure 1(b), were used for charge weight of 22.68 kg. The box was approximately half full as shown in the figure.

(3) M-24 metal-lined wood boxes, Figures 1(c, d), were used for 45.4 kg and 65.8 kg quantities of M10, with boosters placed as shown.

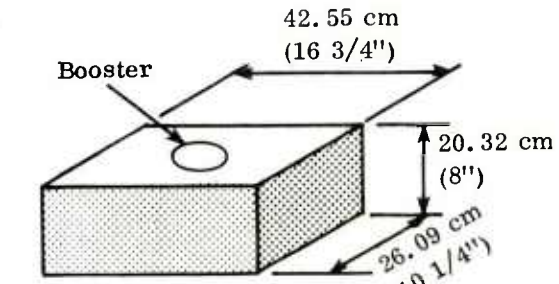
(4) M-25 stainless steel vented container, Figure 1(e) was used for 45.4 kg quantities of M10 propellant.

A conical shaped booster charge of Composition C-4 high explosive was placed in the center of the top of each container, buried such that the apex was level with the top surface of the test material as shown in Figure 1(f). The booster was detonated with an engineers' special J-2 Blasting Cap inserted at the apex and embedded to the center of the cone. A single test for each configuration was performed using a booster equal to 1 percent by weight of the test charge, and subsequent visual observations indicated the absence of unburned propellant. However, since the TNT equivalent weight of C-4 is factored out during data analysis, 1.5 to 2 percent boosters were used to assure complete detonation in subsequent tests. Three or four tests were performed at each specified charge weight.

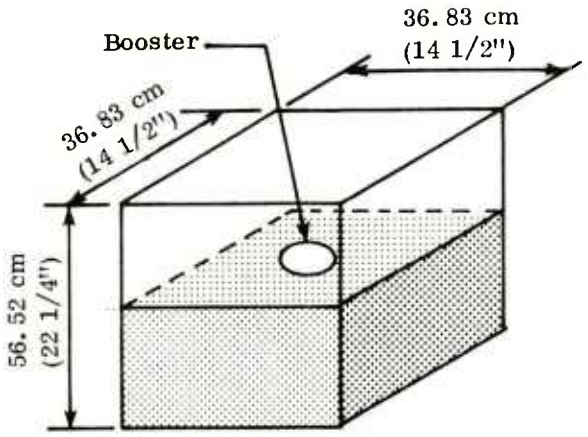
The test charge for each configuration was placed on a 0.61 by 0.61 by 0.0064m thick 1010 carbon steel witness plate in the center of the test area shown in Figure 2. The area was refurbished after each test subsequent to measurement of crater diameter and depth.

INSTRUMENTATION

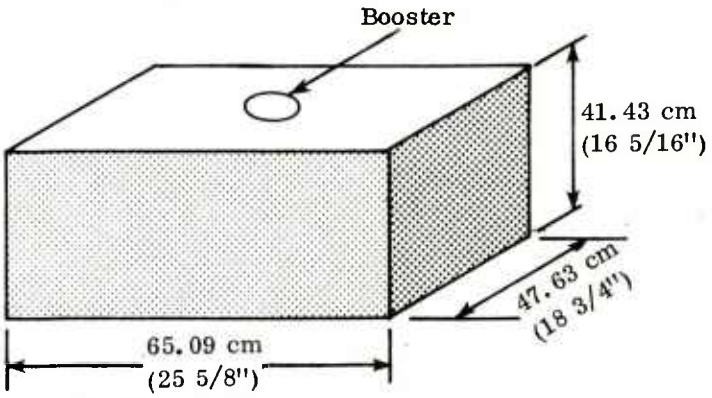
Twelve Susquehanna Instruments Model ST-7 side-on blast transducers were mounted in wooden blocks that were buried so that the sensor was at ground level in two arrays within the test area shown in Figure 3. Distances between transducers and charges were calculated to correspond to scaled distances of 1.19, 1.61, 2.13, 3.57, 7.14 and 15.87 meter/kg$^{1/3}$. The transducers were individually calibrated prior to each test series with pressure pulses from a standard solenoid-actuated air pressure calibration fixture, adjusted to correspond to expected blast pressure on an assumed TNT equivalency of 100 percent. This calibration was verified initially by measuring free field blast pressures from 0.454 kg bare spherical charges of 50/50 pentolite. Signal line continuity and channelization were checked prior to each test. Details of



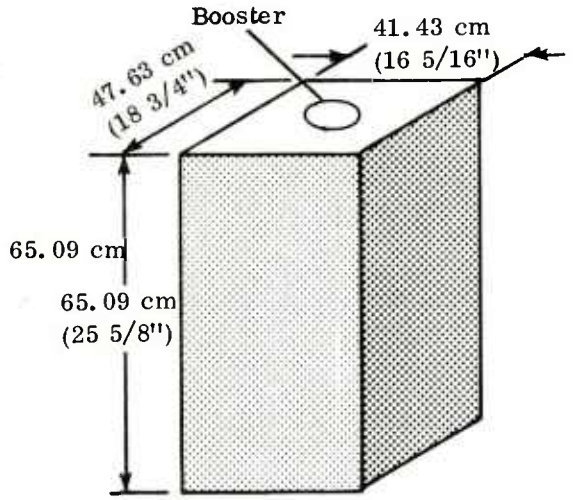
(a) scaled conveyor bucket
(11.34 kg)



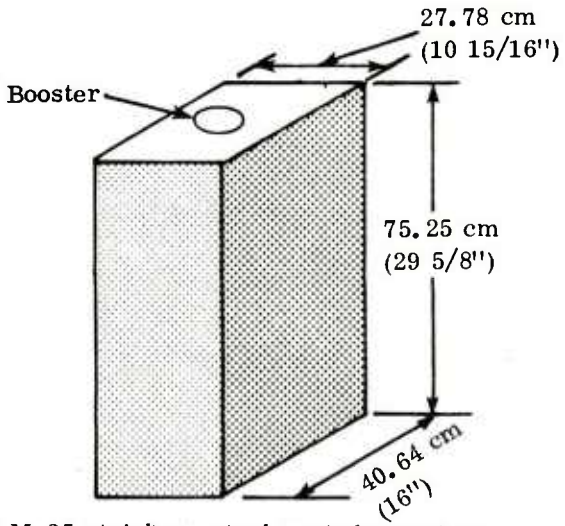
(b) M-17 metal lined wooden box
(22.7 kg)



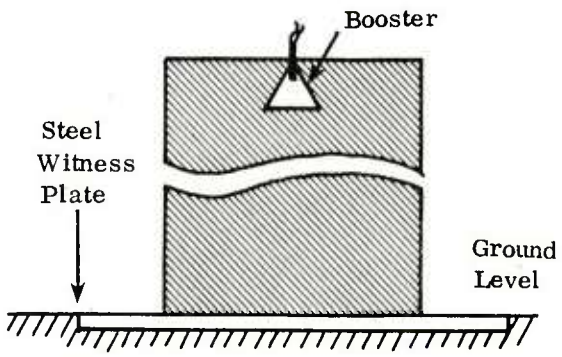
(c) M-24 metal lined wooden box
(45.4 kg)



(d) M-24 metal lined wooden box
(65.8 kg)



(e) M-25 stainless steel vented container
(45.4 kg)



(f) booster and charge placement

Figure 1. Test Container Configurations

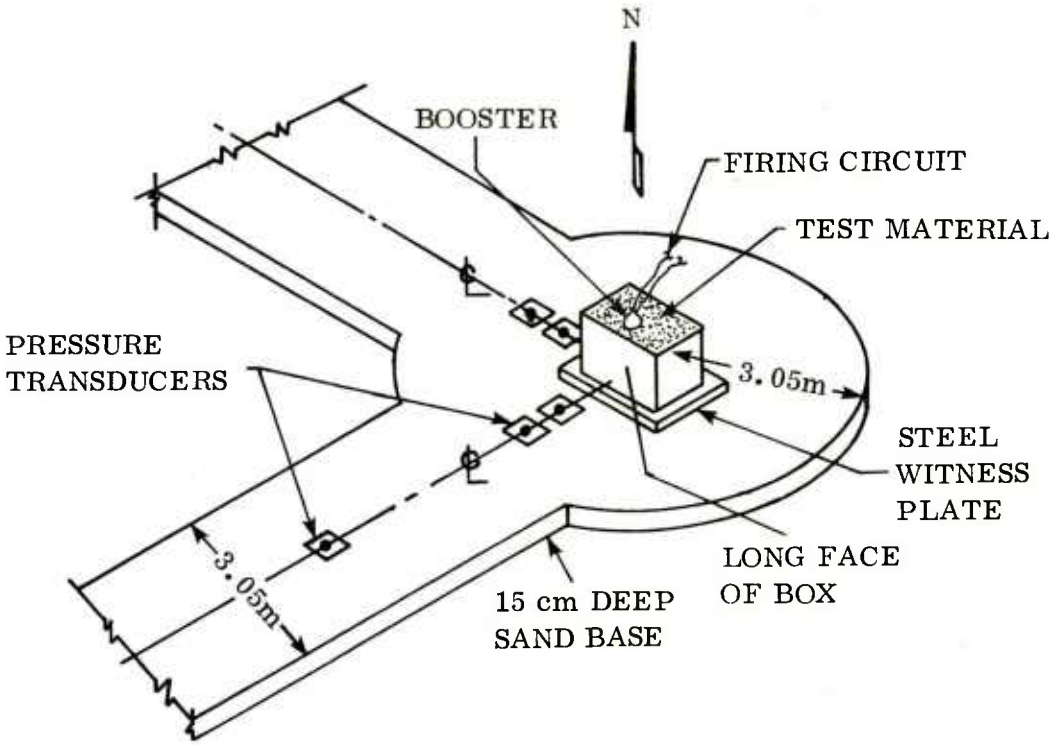


Figure 2. Typical Charge Placement for Equivalency Tests

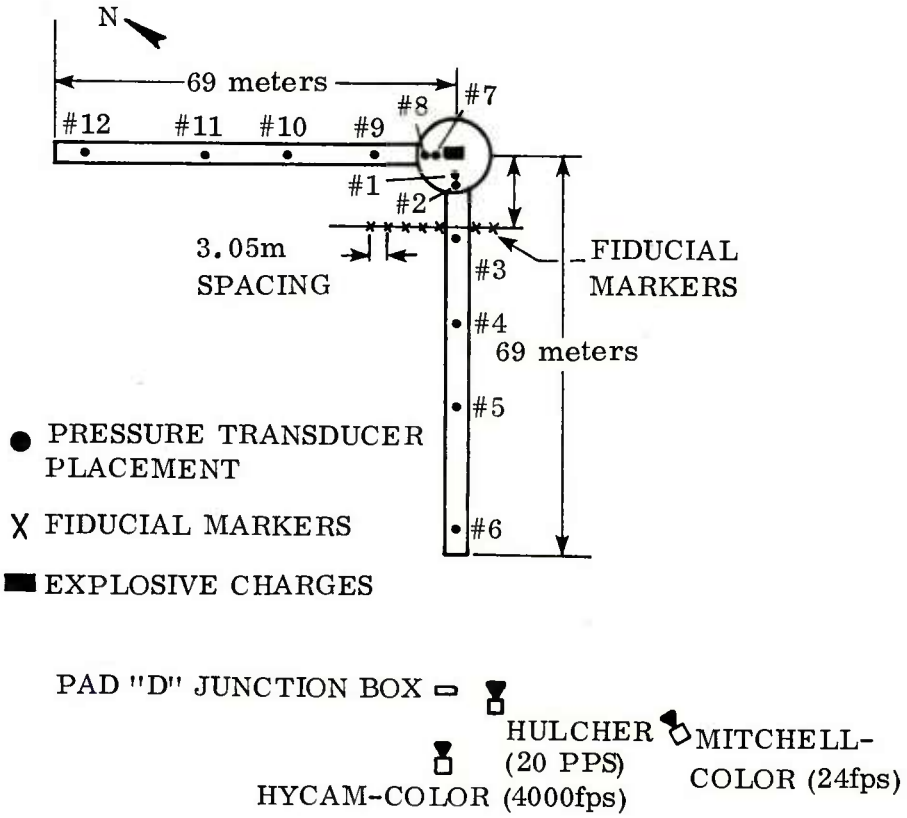


Figure 3. Test Area Showing Transducer and Camera Placement

distances between charge and transducers, calibration pressure and expected peak blast pressures at each distance are shown in Table 1.

Table 1. Transducer Calibration and Placement

Channel Number	Scaled Distance $m/kg^{1/3}$ ($ft/lb^{1/3}$)	Calibration Pressure kPa (psig)	Expected Pressure kPa (psig)	Distance in Meters (Ft) From Charge			
				Charge Weight 11.34 kg (25 lb.)	Charge Weight 22.68 kg (50 lb)	Charge Weight 45.4 kg (100 lb)	Charge Weight 65.8 kg (145 lb)
1, 7	1.19 (3.0)	689 (100)	868.6 (126.0)	2.67 (8.77)	3.37 (11.05)	4.24 (13.92)	4.80 (15.76)
2, 8	1.61 (4.05)	414 (60)	437.5 (66.35)	3.61 (11.84)	4.55 (14.9)	5.73 (18.80)	6.49 (21.28)
3, 9	2.13 (5.38)	207.8 (30)	250.5 (36.33)	4.80 (15.73)	6.04 (19.8)	7.61 (24.97)	8.61 (28.26)
4, 10	3.57 (9.0)	68.9 (10)	87.9 (12.74)	8.02 (26.32)	10.11 (33.2)	12.73 (41.77)	14.41 (47.28)
5, 11	7.14 (18.0)	34.5 (5)	24.9 (3.605)	16.04 (52.63)	20.21 (66.3)	25.47 (83.55)	28.82 (94.55)
6, 12	15.87 (40.0)	34.5 (5)	7.45 (1.081)	35.64 (117.0)	44.92 (147.4)	56.59 (185.66)	64.05 (210.14)

Each transducer with inherent charge amplifier was connected to an underground coaxial cable system which leads into the instrumentation building, approximately 600 feet from the test area. All signals were amplified by Dynamic 6457 units and recorded on a 14-track Sangamo Model 4700 tape recorder at 152 centimeters per second (60 ips), along with an initial timing signal from a break wire placed on the booster charge and one millisecond timing pulses. The nominal response (-3dB) for this recording system is 30 kHz . Data from channels 1, 2, 7 and 8 (i.e., the closest transducers) were simultaneously recorded at 305 centimeters per second (120 ips) on a Honeywell Model 96 tape recorder. Data from the magnetic tapes, read at 19.05 cm per second, was recorded on a Honeywell Model 1612 oscillograph operated at 101.6 cm per second.

Photographic coverage was restricted to one test for each configuration, see Figure 3. Motion picture coverage included a Hycam Model 41.004 camera operated at 1500-4000 frames per second (fps) and one Mitchell camera operated at 24 fps. One Hulcher Model 40, 70-mm sequencing still camera, was operated at 20 pictures per second. Fiducial markers in the field of view with 3.05 meter spacing aided in determination of fireball diameter. Standard meteorological data was recorded for each test.

DATA ANALYSIS

Peak blast overpressure, time of arrival and scaled positive impulse information was obtained in direct analog form from the oscillograph records. After exclusion of poor results that could be attributed to instrumentation malfunction, impingement of fragments on the transducer elements or improper calibration, average values for peak pressure and scaled positive impulse were calculated for each weight and scaled distance.

The average peak pressures were compared directly with standard reference curves for hemispherical TNT surface blasts (Reference 1) to derive TNT equivalency (E_p) as a percentage by weight based on equivalent side-on blast pressure at equal distances from the charge:

$$E_p = 100 \left[\frac{W_{TNT}}{W_{M10}} \right]_{\substack{\text{constant} \\ \text{pressure} \\ \text{and distance}}} = 100 \left[\frac{Z^3_{M10}}{Z^3_{TNT}} \right]_{\substack{\text{constant} \\ \text{pressure}}} \qquad (1)$$

where W is the weight of explosive, Z is scaled distance, P is the peak blast pressure and the subscripts refer to the explosive material.

Calculations of TNT impulse equivalency were based on the analytical method of McKown and McIntyre (Reference 2). Thus the impulse equivalency, E_I, is given in terms of measured parameters by

$$E_I = 0.0163 \, Z_{M10}^{1.42} \, I_{M10}^{1.58}, \qquad (2)$$

where I is the measured impulse in (kPa) (msec)/$kg^{1/3}$ at scaled distance Z in meters/$kg^{1/3}$.

An analysis of contributions to the measured peak pressure and impulse showed that the weight of booster material used for these tests is insignificant. To a first approximation, the TNT equivalencies of the C4 booster and the M10 propellant were assumed equal, i.e., the actual explosive charge weight is the sum of the booster and test material. Neglect of the booster then corresponds

to an error of 2 percent in weight of explosive and a maximum error of 1 percent in scaled distance. Uncertainties of this magnitude produce corresponding errors in pressure and impulse that are considerably below the standard deviation of reference tables (Reference 1) and are an order of magnitude less than experimental errors in normal blast measurements. The same conclusion is obtained for any reasonable assumption concerning the actual equivalency of the booster material; the contribution may be totally neglected for booster weights on the order of 2 percent, test material equivalencies in the range of 50 percent to 300 percent, and scaled distances in the range from 1 to 16 $m/kg^{1/3}$.

TEST RESULTS

Data sheets for all tests with pertinent measured parameters are given in Appendix A. Selected pretest and posttest still photographs are given in Appendix B. Test numbers shown are for local reference only and provide access to original range data files.

Average pressure, scaled positive impulse, and time of arrival data, with standard deviations, are summarized by test configuration in Tables 2 thru 6 and Figures 4 thru 9. Percent TNT equivalencies for all charge weights are shown in Figure 10 as functions of scaled distance. Composite equivalency curves based upon similar ratios of height to weight (h/w) are shown in Figure 11 and are reproduced in the Summary section of this report. Fireball duration and diameter as measured from the high speed motion pictures are given in Table 8.

DISCUSSION

The plots of peak pressure versus scaled distance (Figures 4 thru 8) from the orthorhombic configuration show the same general trend that has been observed in recent TNT equivalency determinations on other explosive and propellant materials. Compared to corresponding TNT hemispherical surface burst, the observed pressures are greater at the near field values ($Z \leq 6$ $m/kg^{1/3}$) and less than the standard for far field values ($Z > 6$ $m/kg^{1/3}$). Impulse versus distance data shows similar tendencies, although impulse equivalencies were significantly higher than the pressure equivalencies at the near field values. Pressure and impulse data obtained from the 11.34, 22.78 and 45.5 kg charge masses in similar ratio $h/w < 1$ are fit by a single curve. Similarly, data from the 45.4 and 65.8 kg with similar ratio $h/w > 1$ also plot as a single curve. The composite data is shown in Tables 7 and 8 and Figures 9, 10 and 11. Essentially S-shaped TNT Equivalency curves were obtained by use of the mean data, see Figure 12.

Figure 13 is a graphical presentation of the deviation from cube root scaling using the M10 propellant data. A positive slope indicates that increasing charge masses at constant scaled distance results in an increase in pressure or impulse equivalency. Conversely, a negative slope is indicative of a decrease in pressure

or impulse equivalency for increased charge masses. Although a positive slope was obtained for side-on pressure and a negative slope was observed for scaled impulse, to within experimental error the data correlated with the standard TNT cube root scaling for all charge weights tested.

Fireball characteristics shown in Table 9 were obtained from the high speed motion pictures taken during a singular test at each charge weight. The fireball diameter and duration were compared to predictions from equations given by High (Reference 3):

$$D = 3.86\ W^{0.320}\ ;\ T_D = 0.299\ W^{0.320}$$

where D is the fireball diameter in meters, W is the weight of material in kilograms, and T_D is the duration in seconds.

The observed fireball diameters do not agree with predicted values except for the data from the 11.34 kg test, and there does not appear to be any general correlation in the data. The fireball durations are fit reasonably well if the constant is revised, i.e.,

$$T_D \approx 0.13\ W^{0.320}$$

It is apparent that variations due to container construction, geometry, and ullage prohibit a detailed analysis with the limited data from these tests.

The 24 frame per second motion pictures were used only for test documentation and for verification of the fireball information obtained from the high speed film. The Hulcher camera provided excellent documentary photographs of the reaction characteristics, as shown in Appendix B.

CONCLUSIONS

1. The pressure and impulse TNT equivalency of M10, Type 2, SP 0.018 propellant in four orthorhombic configurations varies with scaled distance and is greater than 100 percent at near field values ($Z < 3 m/kg^{1/3}$) and less than 100 percent at far field values ($Z \geq 3 m/kg^{1/3}$).

2. Within experimental error, the pressures and impulses from the orthorhombic and conveyor bucket configurations (11.34 kg, 22.68 kg, 45.36 kg, 65.77 kg) scaled according to the cube root of charge weight.

3. The blast output from M10 propellant is dependent upon the configuration in which it is detonated.

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3. R. W. High, Annals of New York Academy of Science 152 I, Pages 441-451 (1968).

Table 2. Summary of Test Results, 11.34 kg Charges

R, meters (ft.)	Z, $m/kg^{1/3}$ ($ft/lb^{1/3}$)	Time of Arrival (ms)	Peak Pressure kPa (psi)	Scaled Positive Impulse $kPa.ms/kg^{1/3}$ ($psi.ms/lbs^{1/3}$)	Pressure TNT Equivalency Percent	Impulse TNT Equivalency Percent
2.67 (8.77)	1.19 (3.00)	0.99 ±0.10	1138±119 (165.±17.3)	593.9±106.8 (66.18±11.9)	155 ±15	385±100
3.61 (11.84)	1.61 (4.05)	1.74±0.15	578.±68 (83.9±9.8)	336.2±52 (37.47±5.8)	140±22	300±35
4.80 (15.7)	2.13 (5.38)	3.17±0.22	245.2±40 (35.57±5.71)	156.2±25.1 (17.41±2.8)	95±24	120±35
8.02 (26.3)	3.57 (9.0)	9.22±0.53	71.7±6.8 (10.4±0.99)	56.7±10.8 (6.32±1.2)	70±10	60±15
16.04 (52.6)	7.14 (18.0)	29.61±0.73	19.2±2 (2.78±0.33)	35.4±4.0 (3.95±0.45)	60±14	75±8
35.7 (117.0)	15.87 (40.0)	83.93±1.03	6.6±0.4 (0.95±0.06)	17.9±1.9 (2.00±0.21)	75±7	85±15

Table 3. Summary of Test Results, 22.68 kg Charges

R, meters (ft.)	Z, $m/kg^{1/3}$ ($ft/lbs^{1/3}$	Time of Arrival (ms)	Peak Pressure kPa (psig)	Scaled Positive Impulse $kPa.ms/kg^{1/3}$ ($psi.ms/lb^{1/3}$)	Pressure TNT Equivalency Percent	Impulse TNT Equivalency Percent
3.37 (11.1)	1.19 (3.0)	1.25±0.09	1146±128 (163.3±18.6)	492.3±66.4 (54.86±7.4)	145±20	345±70
4.55 (14.9)	1.61 (4.05)	2.09±0.18	634±42 (91.9±6.05)	296.9±70.0 (33.09±7.8)	155±15	250±95
6.04 (19.8)	2.13 (5.38)	3.76±0.12	337±92 (48.86±13.4)	141.4±17.9 (15.76±2.0)	150±60	115±40
10.1 (33.2)	3.57 (9.0)	10.16 ± 0.17	79.3±4.5 (11.50±0.65)	57.7±8.1 (6.43±0.9)	85±5	60±7
20.2 (66.3)	7.14 (18.0)	37.43±0.19	18.3±1.0 (2.66±0.15)	34.6±2.7 (3.86±0.3)	60±5	75±8
44.9 (147.4)	15.87 (40.0)	106.21±0.46	7.7±1.7 (1.11±0.24)	17.0±3.6 (1.90±0.4)	90±25	80±25

Table 4. Summary of Test Results 45.4 Charges With a Ratio h/w < 1

R, meters (ft.)	Z, $m/kg^{1/3}$ ($ft/lb^{1/3}$)	Time of Arrival (ms)	Peak Pressure kPa (psig)	Scaled Positive Impulse $kPa.ms/kg^{1/3}$ ($psi.ms/lbs^{1/3}$)	Pressure TNT Equivalency Percent	Inpulse TNT Equivalency Percent
4.24 (13.92)	1.19 (3.0)	1.66±0.20	1066.6±152 (154.7±22.1)	416.7±90 (46.44±10)	135±30	255±70
5.73 (18.80)	1.61 (4.05)	2.81±0.30	619±32 (89.7±4.7)	293.3±72 (32.69±8)	150±10	230±70
7.61 (24.97)	2.13 (5.38)	4.40±0.45	367±83 (53.2±12.0)	167.8±27 (18.7±3.0)	165±45	125±25
12.73 (41.77)	3.57 (9.0)	14.67±0.75	71.7±7.1 (10.4±1.00)	58.9±2.2 (6.56±0.24)	75±10	65±5
25.47 (83.55)	7.14 (18.0)	47.17±1.62	18.8±3.4 (2.72±0.5)	28.5±2.1 (3.18±0.23)	60±15	55±10
56.59 (185.66)	15.87 (40.0)	134.04±2.18	7.10±1.6 (1.03±0.23)	10.1±2.7 (1.12±0.3)	95±20	55±15

Table 5. Summary of Test Results 45.4 kg Charge in the M-25 Stainless Steel Vented Container With a Ratio h/w > 1

R, meters (ft.)	Z, $m/kg^{1/3}$ ($ft/lbs^{1/3}$)	Time of Arrival (ms)	Peak Pressure kPa (psig)	Scaled Positive Impulse $kPa \cdot ms/kg^{1/3}$ ($psi \cdot ms/lbs^{1/3}$)	Pressure TNT Equivalency Percent	Impulse TNT Equivalency Percent
4.24 (13.92)	1.19 (3.0)	1.43±0.11	1350±59 (195.8±8.5)	353±73 (39.3±8.1)	185±15	215±70
5.73 (18.80)	1.61 (4.05)	2.45±0.13	827±155 (120±22.5)	269±63 (30±7)	200±55	175±25
7.61 (24.97)	2.13 (5.38)	4.37±0.5	333±70 (48.3±10.1)	186±22 (20.7±2.5)	150±45	185±35
12.73 (41.77)	3.57 (9.0)	12.94±1.72	78.6±8.3 (11.4±1.2)	52±9.9 (5.8±1.1)	85±15	45±25
25.47 (83.55)	7.14 (18.0)	45±1.74	21.7±2.8 (3.15±0.4)	26.5±1.8 (2.95±0.2)	80±20	45±10
56.59 (185.66)	15.87 (40.0)	132.9±2.1	7.1±0.8 (1.03±0.12)	6.3±1.8 (.7±0.2)	60±20	15±5

Table 6. Summary of Test Results 65.77 kg Charges

R, meters (ft)	Z, $m/kg^{1/3}$ ($ft/lbs^{1/3}$)	Time of Arrival (ms)	Peak Pressure kPa (psig)	Scaled Positive Impulse $kPa.ms/kg^{1/3}$ ($psi.ms/lbs^{1/3}$)	Pressure TNT Equivalency Percent	Impulse TNT Equivalency Percent
4.80 (15.76)	1.19 (3.0)	1.75±0.15	934±113 (135.5±16.4)	340.6±119 (37.96±13.3)	110±20	180±48
6.49 (21.28)	1.61 (4.05)	2.72±0.36	587±85 (85.1±12.3)	368±130 (41.02±14.5)	130±15	350±49
8.61 (28.26)	2.13 (5.38)	4.62±0.67	312±90 (45.2±13.04)	161.3±33 (17.98±3.7)	160±40	150±25
14.41 (47.28)	3.57 (9.0)	13.97±1.64	90.4±14.2 (13.11±2.06)	68.±15 (7.58±1.7)	105±20	75±28
28.82 (94.55)	7.14 (18.0)	50.5±1.97	21.1±1 (3.06±0.13)	29.8±5.5 (3.32±0.61)	75± 5	60±16
64.05 (210.14)	15.87 (40.0)	147.8±1.98	8.1±1.37 (1.17±0.2)	11±3.6 (1.23±0.4)	110±30	40±12

Table 7. Summary of Test Results of 11.34, 22.68 and 45.36 kg Charge Weight Combined with Ratio $h/w < 1$

Scaled Distance Z, $m/kg^{1/3}$ ($ft/lbs^{1/3}$)	Scaled Time of Arrival $ms/kg^{1/3}$	Peak Pressure kPa (psig)	Scaled Positive Impulse $kPa \cdot ms/kg^{1/3}$ ($psi \cdot ms/lbs^{1/3}$)	Pressure TNT Equivalency Percent	Impulse TNT Equivalency Percent
1.19 (3.0)	0.44±0.03	1027±83 (149±12)	501±72 55.8±8)	113±10	326±39
1.61 (4.05)	0.76±0.04	613±48 (88.9±7)	318±36 (35.4±4)	143±14	279±42
2.13 (5.38)	1.32±0.07	299±62 (43.4±9)	149±18 (16.6±2)	138±31	128±22
3.57 (9.0)	3.84±0.18	74±7 (10.7±1)	59.2±4.5 (6.6±0.5)	87±13	64±6
7.14 (18.0)	13.17±0.28	19±2 (2.7±0.3)	32.3±6.3 (3.6±0.7)	62±11	71±8
15.87 (40.0)	37.47±0.45	7.6±1.4 (1.1±0.2)	16.6±2.7 (1.85±0.3)	93±46	77±15

Table 8. Summary of Test Results of 45.4 and 65.8 kg Charge Weights Combined With Ratio h/w < 1

Scaled Distance Z, $m/kg^{1/3}$ ($ft/lbs^{1/3}$)	Scaled Time of Arrival $ms/kg^{1/3}$	Peak Pressure kPa (psig)	Scaled Positive Impulse $kPa \cdot ms/kg^{1/3}$ ($psi \cdot ms/lbs^{1/3}$)	Pressure TNT Equivalency Percent	Impulse TNT Equivalency Percent
1.19 (3.0)	0.43±0.03	1218±193 (176.6±28)	347±54 (38.7±6)	163±36	211±43
1.61 (4.05)	0.68±0.05	579±83 (83.9±12)	347±54 (38.7±6)	140±29	329±51
2.13 (5.38)	1.19±0.11	325±90 (47.1±13)	169±27 (18.8±3)	151±49	164±29
3.57 (9)	3.28±1.00	81.4±9 (11.8±1.3)	62±9 (6.9±1)	89±17	79±16
7.14 (18)	12.57±0.30	20.9±0.8 (3.03±0.11)	28.7±3.6 (3.2±0.4)	74±6	57±10
15.87 (40)	36.72±0.38	8.5±1.7 (1.24±0.24)	9.2±1.8 (1.03±0.2)	140±55	30±10

Table 9. Fireball Duration and Diameter

Charge Weight, kg (lb)	Maximum Fireball Diameter, meters (ft)	Fireball Duration, ms
11.34 (25)	9.14 (30)	300
22.68 (50)	18.29 (60)	300
45.4 (100)	19.81 (65)	550
65.77 (145)	30.48 (100)	550

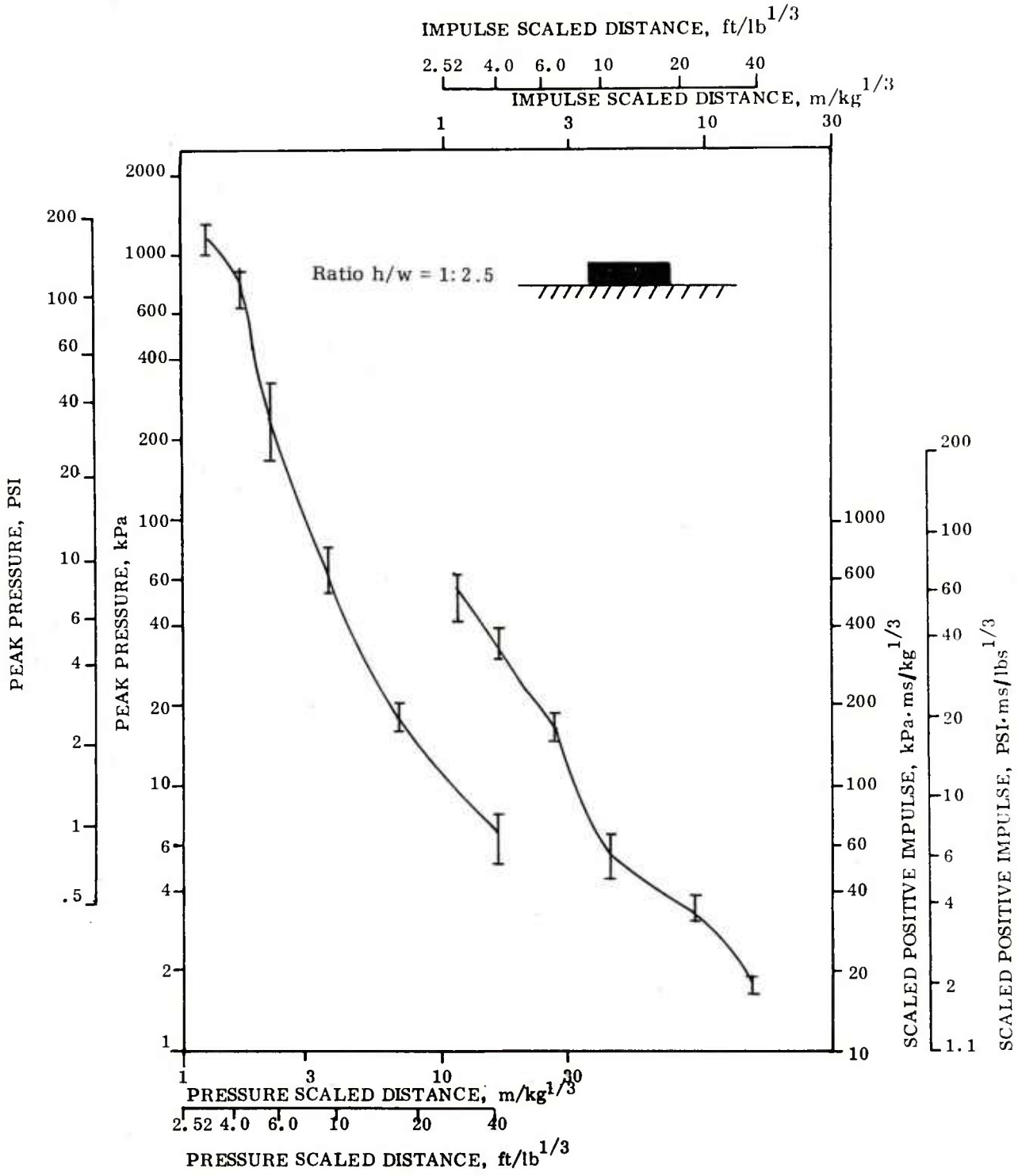


Figure 4. Pressure and Impulse vs. Scaled Distance, 11.34 kg Charges

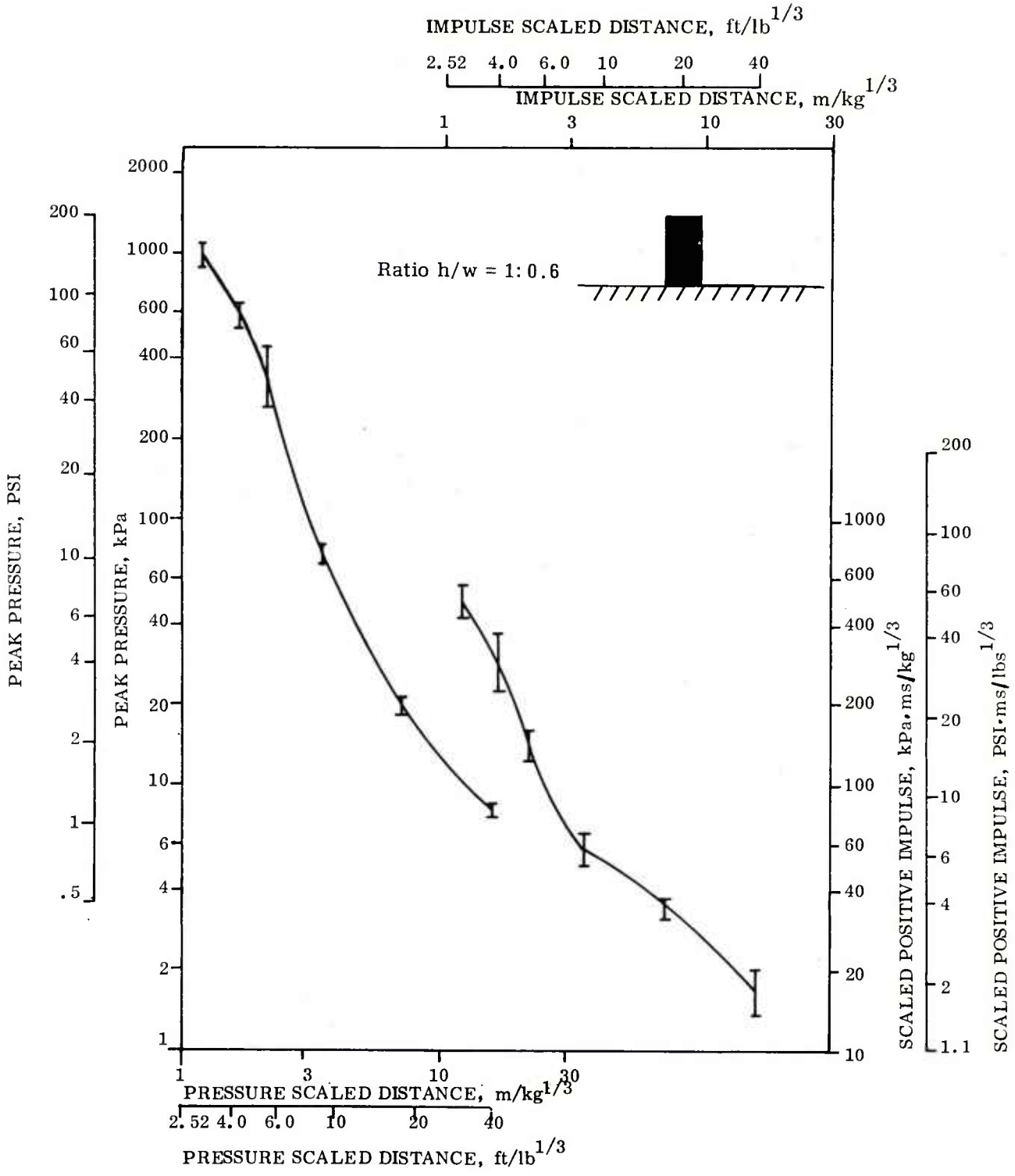


Figure 5. Pressure and Impulse vs. Scaled Distance, 22.68 kg Charges

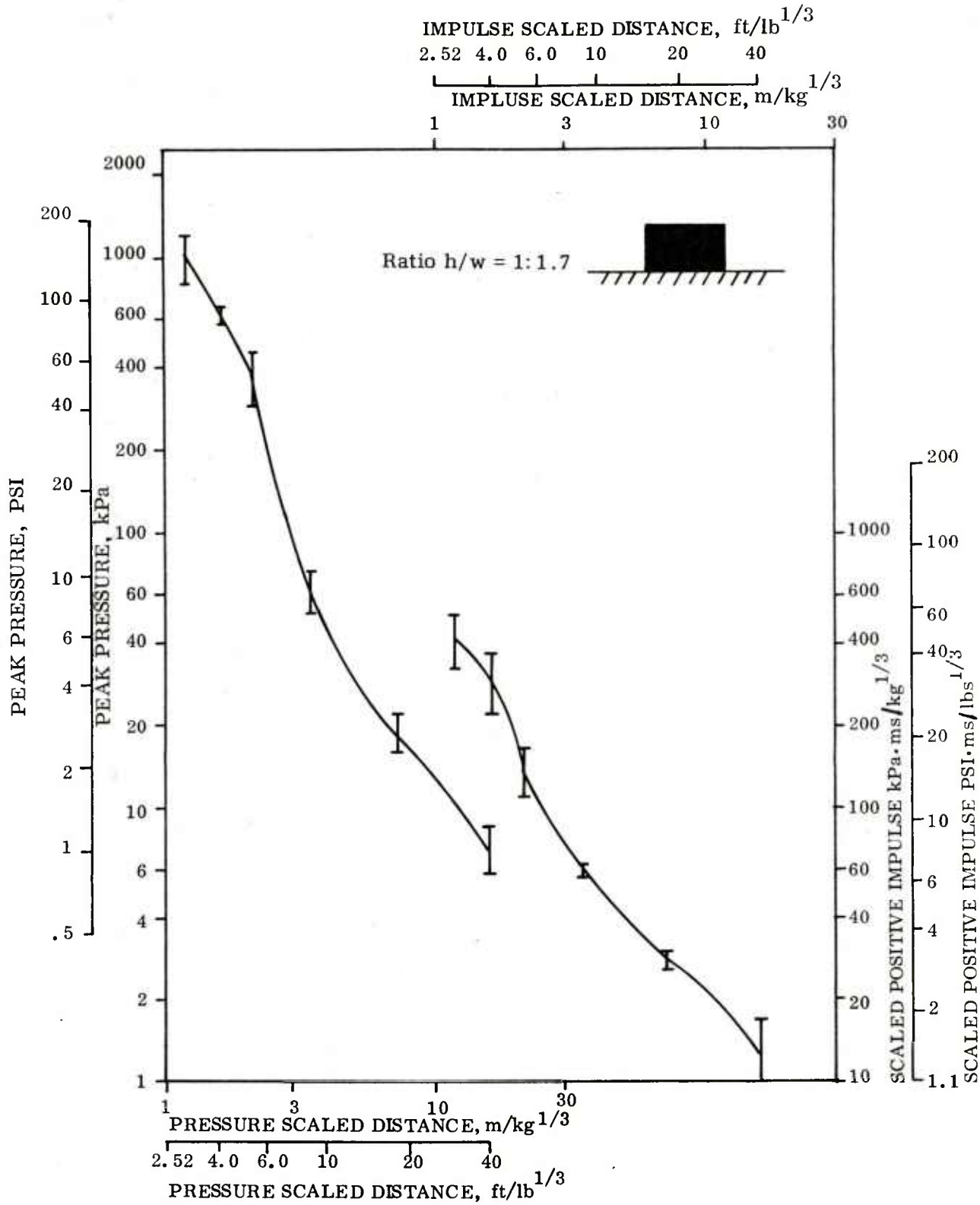


Figure 6. Pressure and Impulse vs. Scaled Distance, 45.4 kg Charges

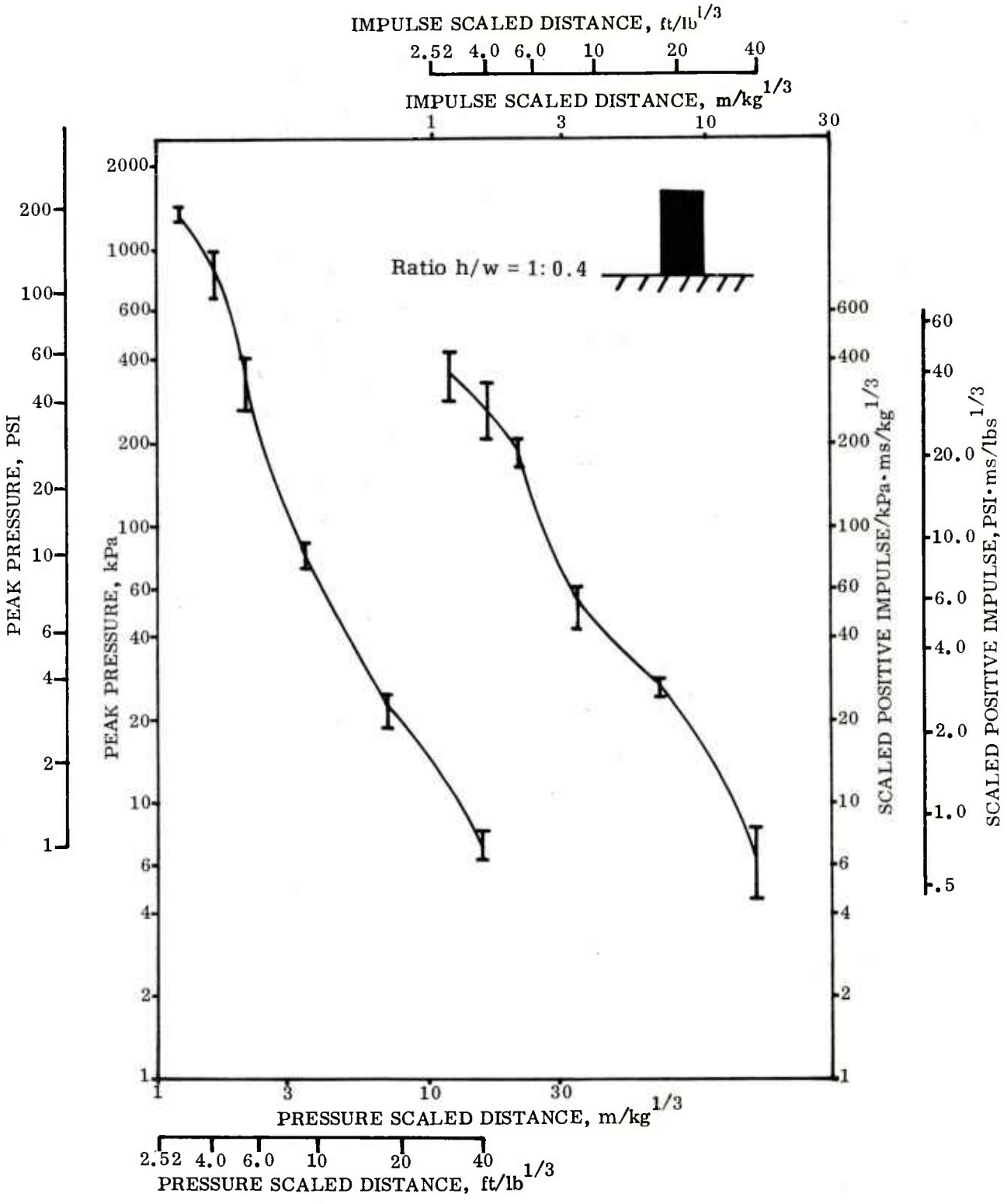


Figure 7. Pressure and Impulse vs. Scaled Distance, 45.4 kg Charge M-25 Stainless Steel Container Ratio h/w = 1: 0.4

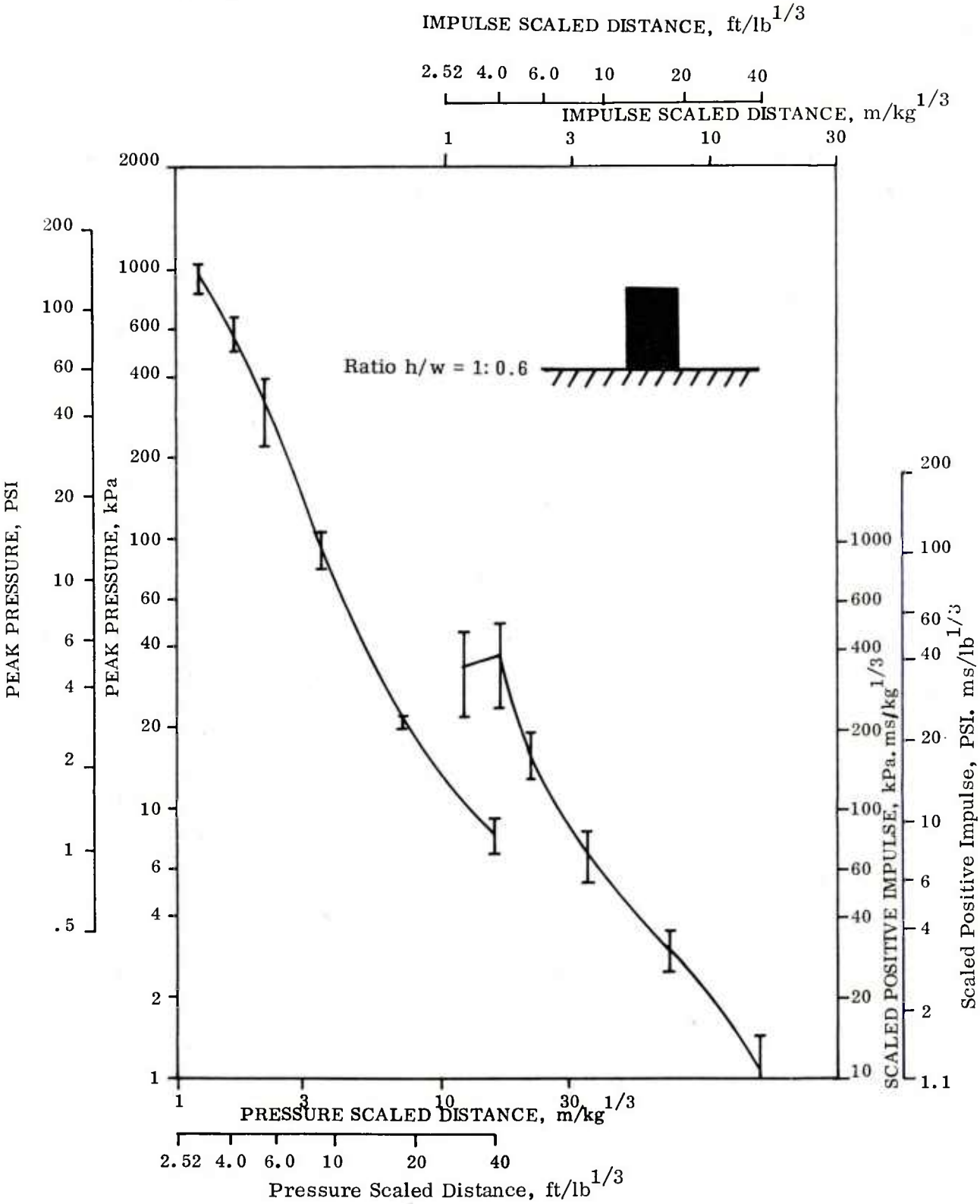


Figure 8. Pressure and Impulse vs. Scaled Distance, 65.77 kg Charges

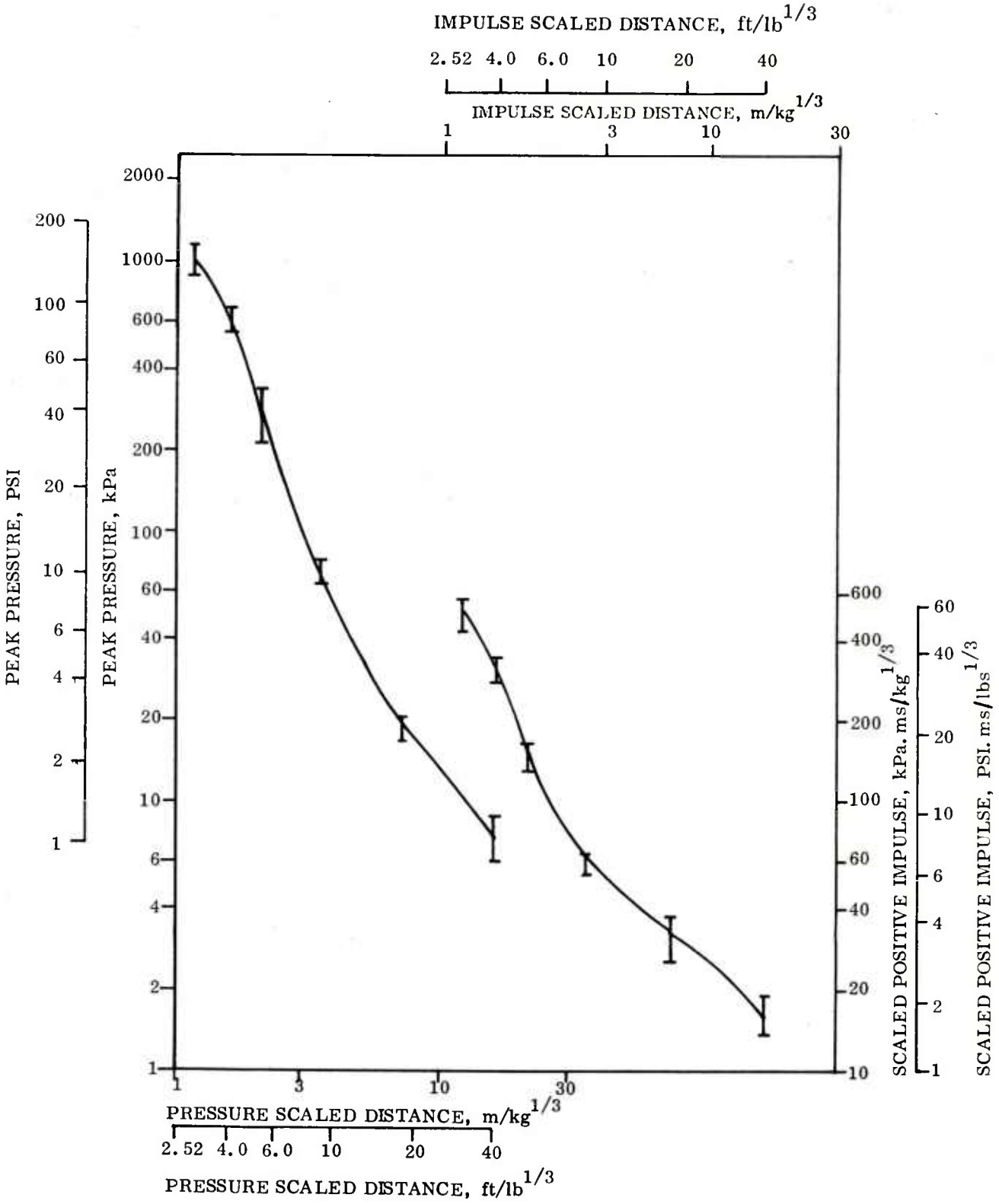


Figure 9. Pressure and Impulse vs. Scaled Distance for Combined Weights of 11.34, 22.68 and 45.4 kg Charges with a Ratio $h/w < 1$

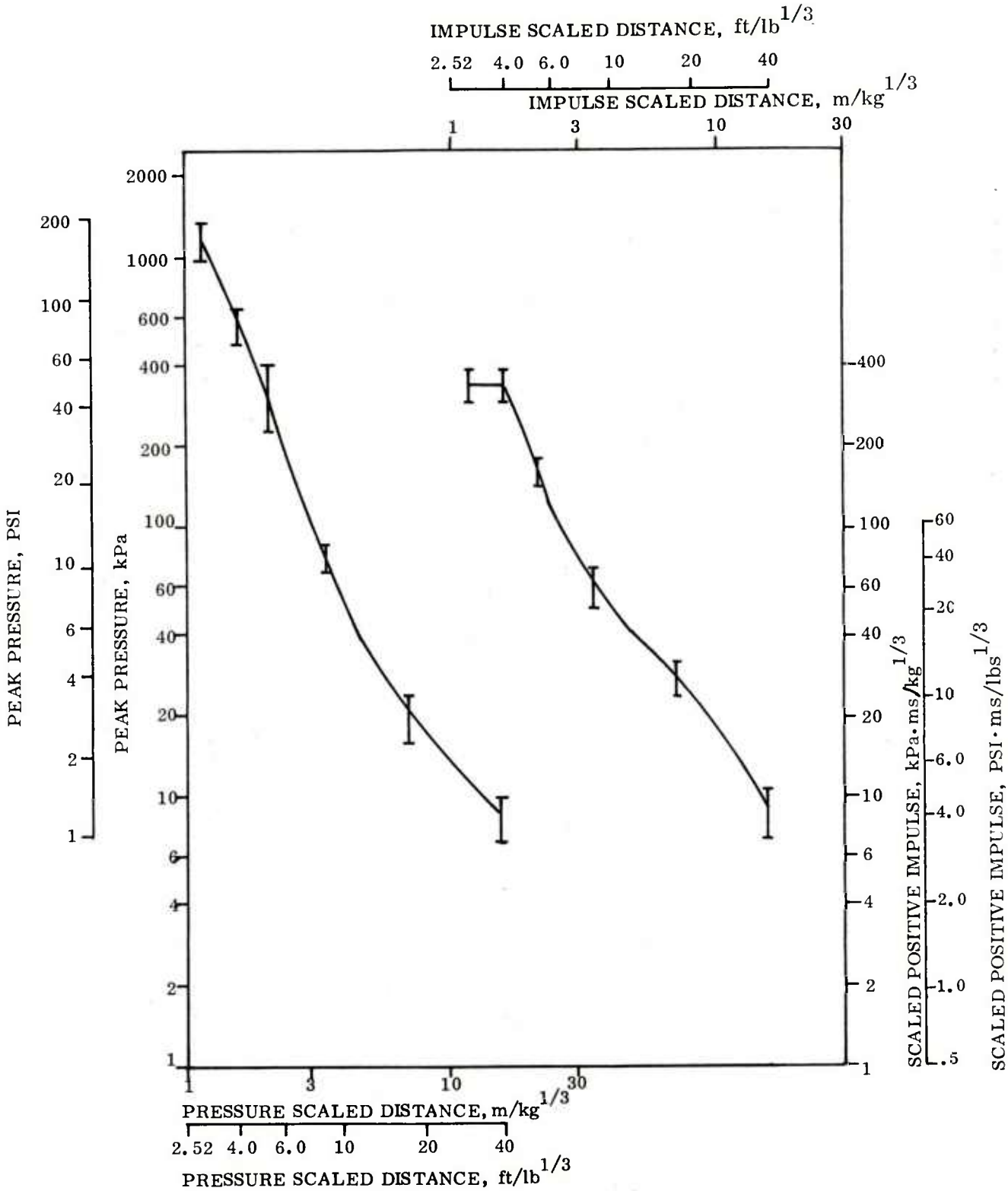


Figure 10. Pressure and Impulse vs. Scaled Distance for Combined Weights of 45.4, 65.8 kg Charges with a Ratio h/w > 1

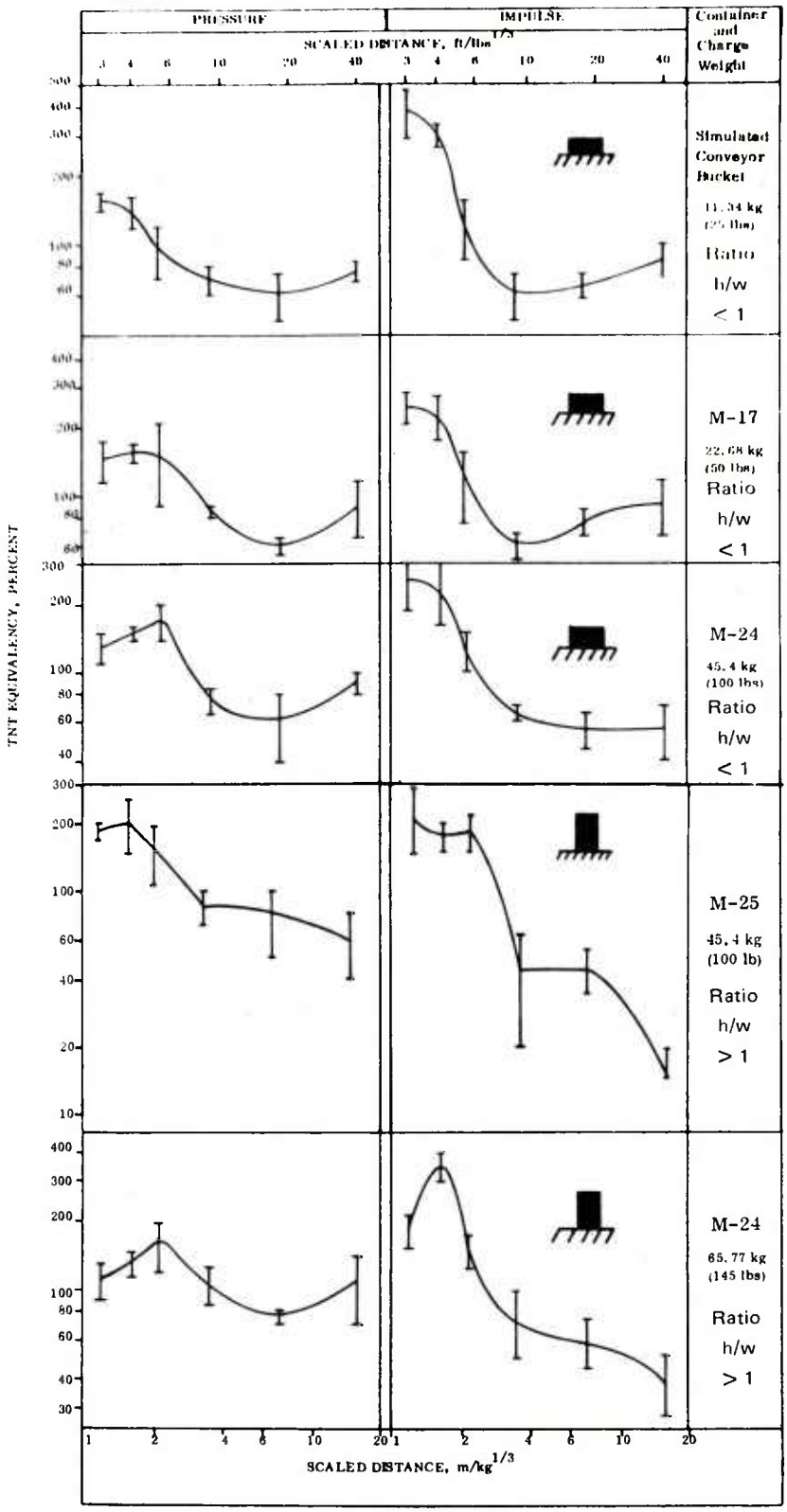


Figure 11. Pressure and Impulse Equivalencies

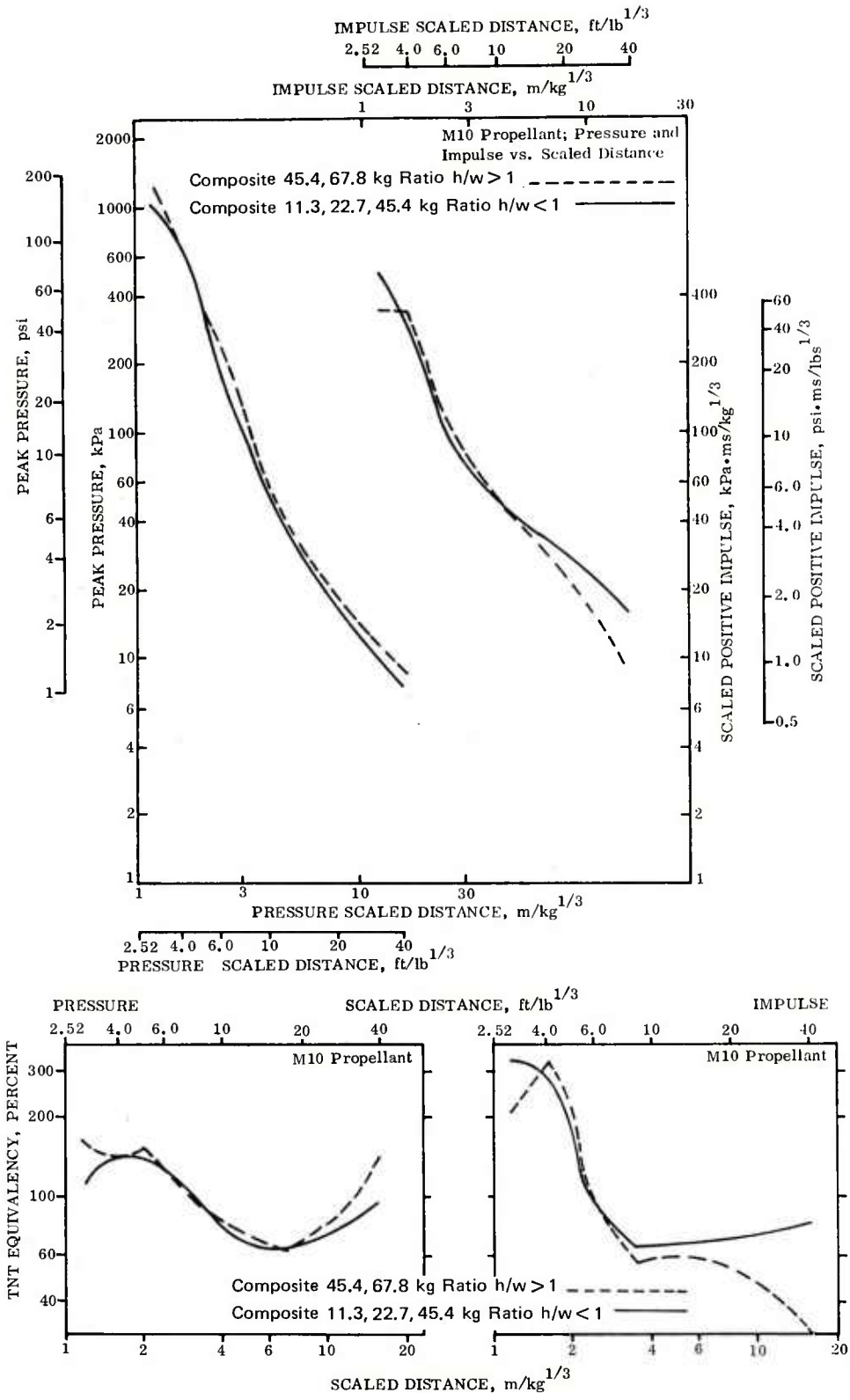
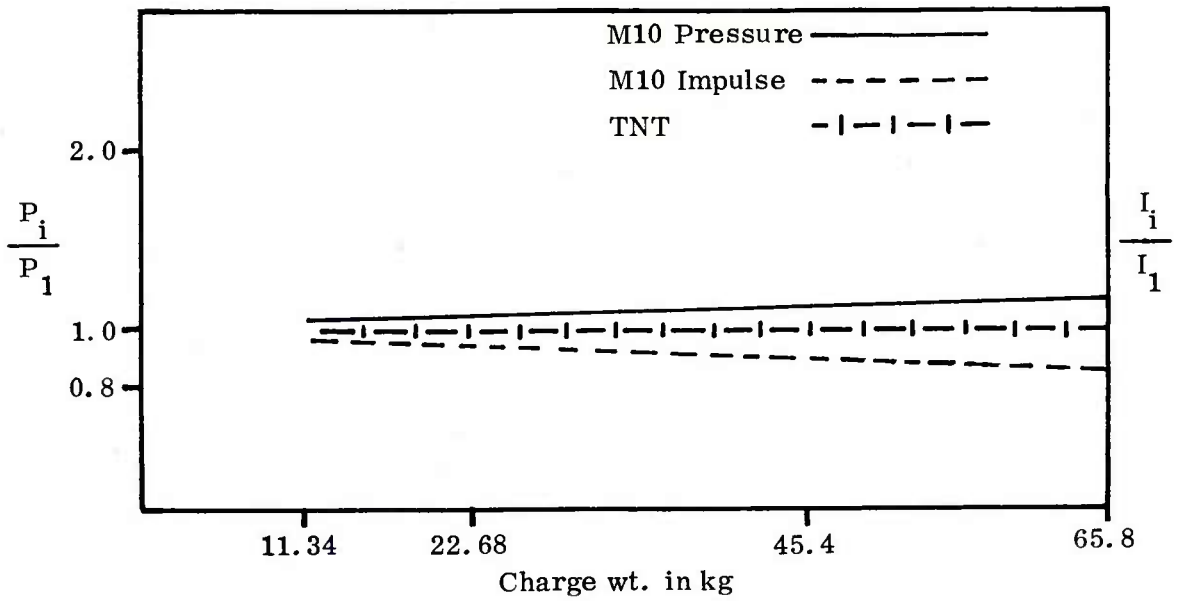


Figure 12. Composite TNT Equivalency of M10 Propellant



Where P_1 = Side on Pressure, 11.34 kg Charge Weight

P_i = Side on Pressure, i^{th} Charge Weight

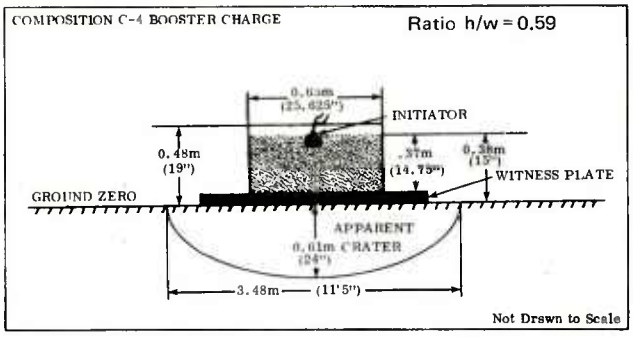
Figure 13. Deviation From Cube-root Scaling of M10 Propellant.

APPENDIX A

FIELD DATA SHEETS

Test Number 15-6-01 A1

TEST TITLE	Explosive Equivalency Testing	DATE	4/8/76
TEST SAMPLE	M10 Propellant; M-24 Shipping Containsr	TIME	1324 Hrs.
SAMPLE WEIGHT	100 lbs/45.36 kg	TEMP.	79°F/26.1°C
IGNITION SOURCE	J-2 Engineer's Special Blasting Cap	HUMIDITY	50%
BOOSTER WT.	1 lb./.45 kg Comp C-4, 1% of Charge Wt.	BAR. PRES.	29.86
TEST NUMBER	15-6-01 A_1	WIND DIR.	300°
CONTRACT NO.	NAS8-27750	WIND VEL.	9 Knote



FIELD EVALUATION

No dats channele 3 and 12

Complete detonetion. No unburned propellant wee found.

Box oriented with ende North and Soutb

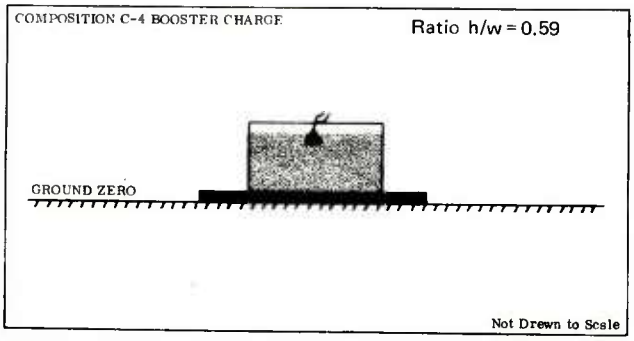
Acouetice dete wss measured.

A_1 Test 45.4 kg M10 Propellant

Channel No.	Distance Meters (ft.)	Peak Pressure kPa (psig)	Scalsd Positive Impulse kPa.msec/kg$^{1/3}$ (psi.msec/lbs$^{1/3}$)	Time of Arrival (msec)	Remarks
1	4.24 (13.92)	965.3 (140)	305 (33.99)	1.6	
7		965.3 (140)	360 (40.12)	1.6	
2	5.73 (18.80)	579.2 (84)	499.6 (55.68)	2.8	
8		867.7 (126)	329.5 (36.72)	2.8	
3	7.61 (24.97)	- -	- -	3.8	No data
9		475.7 (69)	160.7 (17.91)	4.0	
4	12.73 (41.77)	62.1 (9)	61 (6.80)	14.1	
10		96.5 (14)	65.2 (7.27)	15.7	
5	25.47 (83.55)	12.4 (1.8)	29.97 (3.34)	47.0	
11		20.7 (3.0)	27 (3.01)	44.8	
6	56.57 (185.66)	10.3 (1.5)	14.4 (1.60)	134.4	
12		- -	- -	- -	No data

Test Number 15-6-01 A2

TEST TITLE	Explosive Equivelency Teeting	DATE	4/8/76
TEST SAMPLE	M10 Propellent; M-24 Shipping Container	TIME	1457 Hre.
SAMPLE WEIGHT	100 lbs/45.36 kg	TEMP.	82°F/27.8°C
IGNITION SOURCE	J-2 Engineer'e Speciel Blasting Cap	HUMIDITY	34%
BOOSTER WT.	1.5 lbs/0.68 kg Comp C-4, 1.5% of Charge Wt.	BAR. PRES.	29.81
TEST NUMBER	15-6-01 A_2	WIND DIR.	30°
CONTRACT NO.	NAS8-27750	WIND VEL.	5 Knote



FIELD EVALUATION

Complete detonetion

Box ends Eaet & Weet

Crater Dimension 0.64 meter deep by 3.36 meter wide

Acoustice dete wae meesured

A_2 Test 45.4 kg M10 Propellant

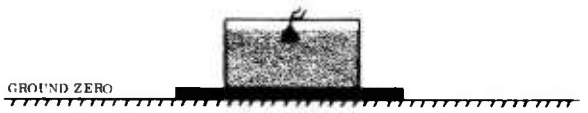
Channel No.	Distance Meters (ft.)	Peak Pressure kPa (psig)	Scalsd Positive Impulse kPa.msec/kg$^{1/3}$ (psi.msec/lbs$^{1/3}$)	Time of Arrival (msec)	Remarks
1	4.24 (13.92)	1310 (190)	416.8 (46.45)	2.0	
7		1034.2 (150)	475.7 (53.01)	1.8	
2	5.73 (18.80)	579.2 (84)	280.2 (31.23)	2.8	
8		661.9 (96)	275.8 (30.74)	2.8	
3	7.61 (24.97)	227.5 (33)	36.6 (4.08)	4.7	
9		413.7 (80)	163.9 (18.27)	4.8	
4	12.73 (41.77)	51.7 (7.5)	59 (6.58)	13.4	
10		72.4 (10.5)	59.3 (6.61)	15.0	
5	25.47 (83.55)	14.5 (2.1)	23.8 (2.65)	45.7	
11		20.7 (3.0)	29.3 (3.27)	48.3	
6	56.59 (185.60)	6.9 (1.0)	13.3 (1.48)	131.3	
12		13.8 (2.0)	10.7 (1.19)	135.8	

Test Number 15-6-01 A3

TEST TITLE	Explosive Equivalency Testing	DATE	4/9/78
TEST SAMPLE	M10 Propellant; M-24 Shipping Container	TIME	1255 Hrs.
SAMPLE WEIGHT	100 lbs/45.36 kg	TEMP.	74°F/23.3°C
IGNITION SOURCE	J-2 Engineer's Special Blasting Cap	HUMIDITY	24%
BOOSTER WT.	1.0 lbs/.45 Kg; Comp C-4 1% of Charge Wt.	BAR. PRES.	30.05
TEST NUMBER	15-6-01 A_3	WIND DIR.	300°
CONTRACT NO.	NAS8-27750	WIND VEL.	11 Knots

COMPOSITION C-4 BOOSTER CHARGE

Ratio h/w = 0.59



Not Drawn to Scale

FIELD EVALUATION

Complete detonation. No unburned propellant. A 1% booster weight is to be utilized throughout the remainder of the test period.

Box ends East and West

Acoustics data was measured

Crater dimension 0.76 meters deep by 4.09 meters wide.

A_3 Test 45.4 kg M10 Propellant

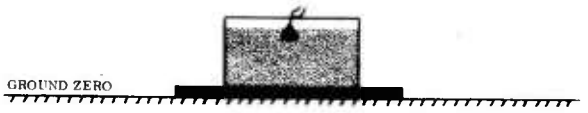
Channel No.	Distance Meters (ft.)	Peak Pressure kPa (psig)	Scaled Positive Impulse kPa.msec/kg$^{1/3}$ (psi.msec/lbs$^{1/3}$)	Time of Arrival (msec)	Remarks
1	4.24 (13.92)	- -	- -	2.0	Bad data ringing
7		827.4 (120)	353.0 (39.34)	1.6	
2	5.73 (18.80)	599.8 (87)	362.6 (40.41)	2.8	
8		661.9 (96)	142.9 (15.93)	2.5	
3	7.61 (24.97)	289.6 (42)	- -	4.4	No peak
9		496.4 (72)	169.9 (18.93)	4.2	
4	12.73 (41.77)	79.3 (11.5)	62.5 (6.97)	14.2	
10		48.3 (7.0)	57.2 (6.37)	14.8	
5	25.47 (83.55)	17.4 (2.52)	28.3 (3.15)	45.9	
11		13.8 (2.0)	31.9 (3.55)	48.6	
6	56.59 (185.66)	6.2 (.9)	15.8 (1.76)	132.1	
12		6.2 (.9)	8.8 (0.98)	136.6	

Test Number 15-6-01 A4

TEST TITLE	Explosive Equivalency Testing	DATE	4/9/76
TEST SAMPLE	M10 Propellant; M-24 Shipping Container	TIME	1408 Hrs.
SAMPLE WEIGHT	100 lbs/45.36 kg	TEMP.	76°F/24.4°C
IGNITION SOURCE	J-2 Engineer's Special Blasting Cap	HUMIDITY	21%
BOOSTER WT.	1.0 lbs/.45 Kg Comp C-4 1% of Charge Wt.	BAR. PRES.	30.03
TEST NUMBER	15-6-01 A_4	WIND DIR.	340°
CONTRACT NO.	NAS8-27750	WIND VEL.	11 Knots

COMPOSITION C-4 BOOSTER CHARGE

Ratio h/w = 0.59



Not Drawn to Scale

FIELD EVALUATION

Complete detonation

Photographic coverage. Hycam 1500 (fps) Hulcher (20 pps) Documentary (24 fps)

Box ends East and West

Crater dimension 0.81 meters deep by 4.1 meters wide

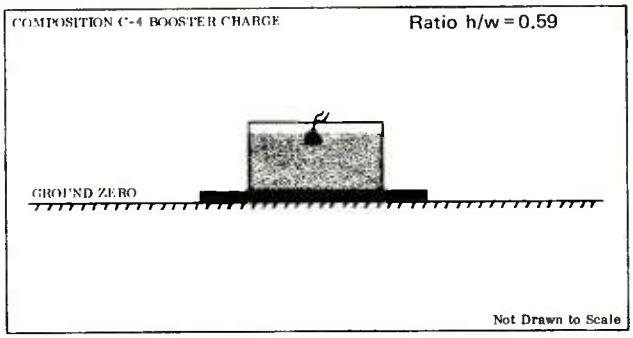
Acoustics data was measured.

A_4 Test 45.4 kg M10 Propellant

Channel No.	Distance Meters (ft.)	Peak Pressure kPa (psig)	Scaled Positive Impulse kPa.msec/kg$^{1/3}$ (psi.msec/lbs$^{1/3}$)	Time of Arrival (msec)	Remarks
1	4.24 (13.92)	--	502.2 (55.96)	1.7	Ringing impulse estimated
7		965.3 (140)	360 (40.12)	1.4	
2	5.73 (18.80)	620.5 (90)	- -	2.8	Hit 3 Txder limited after peak Before return to baseline
8		529.5 (76.8)	176 (19.61)	2.5	
3	7.61 (24.97)	282.7 (41)	- -	4.9	Poor peak
9		372.3 (54)	153.9 (17.15)	4.8	
4	12.73 (41.77)	75.8 (11)	58.1 (6.47)	14.3	
10		48.3 (7)	43 (4.79)	15.3	
5	25.47 (83.55)	19.3 (2.8)	24.9 (2.78)	46.3	
11		15.2 (2.2)	32.6 (3.63)	48.7	
8	56.59 (185.66)	8.9 (1.0)	18.4 (2.05)	131.8	
12		13.8 (2.0)	7.4 (0.82)	136.0	

Test Number 15-6-01 A5

TEST TITLE	Explosive Equivalency Testing	DATE	4/9/76
TEST SAMPLE	M10 Propellant; M-24 Shipping Container	TIME	1505 Hrs.
SAMPLE WEIGHT	100 lbs/45.36 kg	TEMP.	77°F/25°C
IGNITION SOURCE	J-2 Engineer's Special Blasting Cap	HUMIDITY	22%
BOOSTER WT.	1 lbs/.45 kg; Comp C-1 1 % of Charge Wt.	BAR. PRES.	30.02
TEST NUMBER	15-6-01 A5	WIND DIR.	360°
CONTRACT NO.	NAS8-27750	WIND VEL.	10 Knots



FIELD EVALUATION

Box ends orientated East and West

Acoustics data was measured

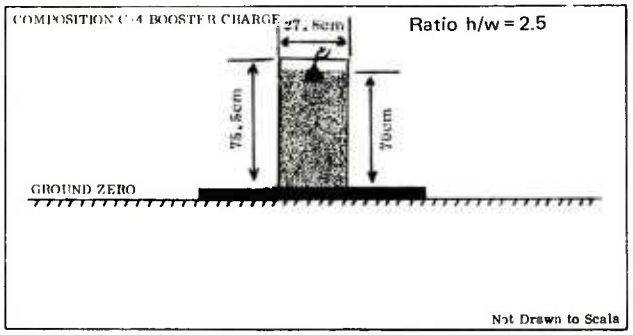
Crater dimansion 0.65 meters by 4.05 meters wide.

A_5 Test 45.4 kg M10 Propellant

Channel No.	Distance Meters (ft.)	Peak Pressure kPa (psig)	Scaled Positive Impulse kPa.msec/kg$^{1/3}$ (psi.msec/lbs$^{1/3}$)	Time of Arrival (msec)	Remarks
1	4.24 (13.92)	- -	- -	1.6	Ringing. Unable to determine peak. Txder was replaced.
7		965.3 (140)	586.8 (65.39)	1.5	
2	5.73 (18.80)	620.5 (90)	331.2 (36.91)	3.6	
8		624.7 (90.6)	126.6 (14.11)	2.7	
3	7.61 (24.97)	- -	- -	3.7	Bad txder.
9		330.9 (48)	131.8 (14.69)	4.7	
4	12.73 (41.77)	68.9 (10)	58 (6.46)	14.2	
10		62.1 (9)	55.8 (6.22)	15.7	
5	25.47 (83.55)	20.7 (3)	23.6 (2.63)	46.3	
11		16.5 (2.4)	34 (3.79)	49.9	
6	56.59 (185.66)	6.2 (0.9)	15.6 (1.74)	132.2	
12		13.8 (2.0)	10.7 (1.19)	136.2	

Test Number 15-6-01 A6

TEST TITLE	Explosive Equivalency Taat	DATE	8/7/76
TEST SAMPLE	M10 Propellant; M25 Shipping Container	TIME	1305
SAMPLE WEIGHT	100 lbs /45.4 kg	TEMP.	85°F/29.4°C
IGNITION SOURCE	J2 Engineer's Special Blasting Cap	HUMIDITY	31%
BOOSTER WT.	1.5 lbs/0.68 kg; Comp 4 1 1/2% of Charge Wt.	BAR. PRES.	30.01
TEST NUMBER	24-6-01A6	WIND DIR.	30%
CONTRACT NO.	NAS8-27750	WIND VEL.	12 Knots



FIELD EVALUATION

Motion Picture Coveraga

Acoustic Measuremants

Complete detonation

Crater Dimenaion .45 metars daep by 3.02 meters wide

A_6 Test 45.4 kg M- M10 Propellant

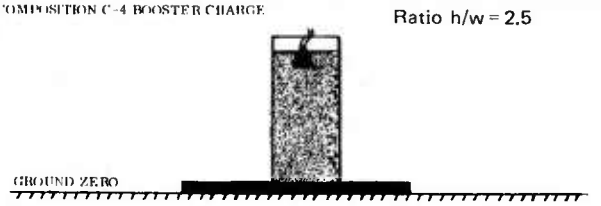
Channel No.	Distance Meters (ft.)	Peak Pressure kPa (psig)	Scaled Positive Impulse kPa.msec/kg$^{1/3}$ (psi.msec/lbs$^{1/3}$)	Time of Arrival (msec)	Remarks
1	4.24 (13.92)	1379 (200)	342.8 (38.20)	1.35	
7		1379 (200)	286.3 (31.91)	1.4	
2	5.73 (18.80)	827.4 (120)	2.9 (24.41)	2.35	
8		827.4 (120)	252.3 (28.12	2.6	Limited
3	7.61 (24.97)	293 (42.5)	173.1 (19.29)	3.55	Limited
9		413.7 (60)	212.1 (23.64)	4.6	
4	12.73 (41.71)	68.9 (10.0)	44.5 (4.96)	11.5	
10		84.1 (12.2)	58.2 (6.49)	14.3	
5	25.47 (83.55)	24.1 (3.5)	21.9 (2.44)	43.8	
11		18.8 (2.7)	34.0 (3.79)	46.8	Double Peak
8	56.59 (185.66)	10.3 (1.5)	4.3 (0.48)	130.4	
12		5.5 (0.8)	7.9 (0.88)	134.2	

Test Number 15-6-01 A7

TEST TITLE	Explosive Equivalency Test	DATE	6/7/76
TEST SAMPLE	M10 Propellant: M2½ Shipping Container	TIME	1418
SAMPLE WEIGHT	15. 1kg (100 lbs)	TEMP.	85°F/29.4°C
IGNITION SOURCE	J2 Engineer's Special Blasting Cap	HUMIDITY	30
BOOSTER WT.	1.5 lbs/0.68 kg; Comp 4 1 1/2% of Charge Wt.	BAR. PRES.	30.00
TEST NUMBER	24-6-01A_7	WIND DIR.	70°
CONTRACT NO.	NAS8-27750	WIND VEL.	4 Knots

COMPOSITION C-4 BOOSTER CHARGE

Ratio h/w = 2.5



Not Drawn to Scale

A_7 Test 45.4 kg M10 Propellant

Channel No.	Distance Meters (ft.)	Peak Pressure kPa (psig)	Scaled Positive Impulse kPa.msec/$kg^{1/3}$ (psi.msec/$lbs^{1/3}$)	Time of Arrival (msec)	Remarks
1	4.24 (13.91)	1379 (200)	628.5 (70.04)	1.6	
7		1261.7 (183)	429.5 (47.86)	1.5	
2	5.73 (18.80)	517.1 (75)	- -	2.8	Limited (did not return to baseline) Bad
8		827.4 (120)	311.1 (34.67)	2.4	Limited
3	7.61 (24.97)	293 (42.5)	173.1 (19.29)	4.7	
9		586.1 (85)	255.6 (23.48	3.8	Limited
4	12.73 (41.71)	46 (6.67)	32 (3.57)	14.55	
10		82.7 (12.0)	72.1 (8.04)	11.4	
5	25.47 (83.55)	24.1 (3.5)	26.2 (2.92)	47.0	Double Peak
11		18.8 (2.73)	27.2 (3.03)	44.0	Double Peak
6	56.59 (185.66)	6.9 (1.0)	4.4 (0.49)	134.0	
12		5.5 (0.8)	7.0 (0.78)	130.0	

FIELD EVALUATION

Acoustica Measurements

Complete Detonation

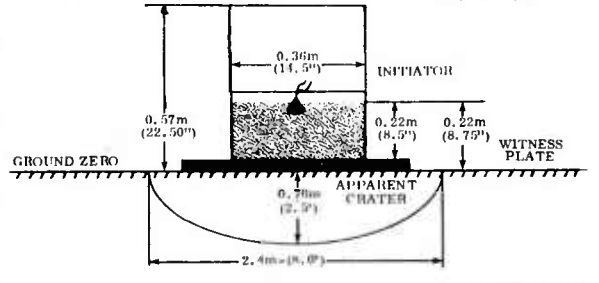
Crater Dimension .47 meters deep by 3.32 meters wide

Test Number 15-6-02 B1

TEST TITLE	Explosive Equivalency Testing	DATE	4/10/78
TEST SAMPLE	M10 Propellant; M-17 Shipping Container	TIME	1030 Hrs.
SAMPLE WEIGHT	50 lbs/22.68 kg	TEMP.	75°F/23.8°C
IGNITION SOURCE	J-2 Engineer's Special Blasting Cap	HUMIDITY	28%
BOOSTER WT.	0.5 lbs/.23 kg, Comp C-4 1% Charge Wt.	BAR. PRES.	30.17
TEST NUMBER	15-6-02 B_1	WIND DIR.	150°
CONTRACT NO.	NAS8-27750	WIND VEL.	4 Knots

COMPOSITION C-4 BOOSTER CHARGE

Ratio h/w = 0.6



Not Drawn to Scale

B_1 Test 22.68 kg M10 Propellant

Channel No.	Distance Meters (ft.)	Peak Pressure kPa (psig)	Scaled Positive Impulse kPa.msec/$kg^{1/3}$ (psi.msec/$lbs^{1/3}$)	Time of Arrival (msec)	Remarks
1	3.37 (11.05)	1241.1 (180)	383.53 (42.74)	1.2	
7		1034.2 (150)	485.74 (54.13)	1.0	
2	4.55 (14.92)	661.9 (96)	436.74 (48.67)	1.9	
8		579.2 (84)	301.42 (33.59)	1.6	
3	6.04 (19.82)	289.6 (42)	46.68 (5.20)	3.4	Bad data
9		393 (57)	174.89 (19.49)	2.8	
4	10.11 (33.16)	82.7 (12)	60.12 (6.70)	9.0	
10		82.7 (12)	37.42 (4.17)	8.8	
5	20.21 (66.31)	17.2 (2.5)	36.61 (4.08)	29.3	
11		18.8 (2.7)	31.88 (3.55)	29.7	
6	44.92 (147.36)	9.0 (1.3)	19.65 (2.19)	83.3	
12		6.9 (1.0)	12.92 (1.44)	84.1	

FIELD EVALUATION

Complete reaction. No unburned propellant

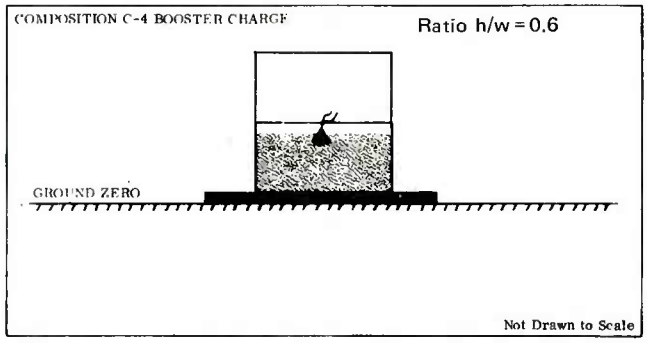
All instrumentation functioned

Crater dimension 8.76 meters deep by 2.4 meters wide

Box orientated North and South

Test Number 15-6-02 B2

TEST TITLE	Explosive Equivalency Testing	DATE	4/10/76
TEST SAMPLE	M10 Propellant; M-17 Shipping Container	TIME	1130 Hrs.
SAMPLE WEIGHT	50 lbs/22.68 kg	TEMP.	75°F/23.8°C
IGNITION SOURCE	J-2 Engineer's Special Blasting Cap	HUMIDITY	26%
BOOSTER WT.	1 lb/.45 kg Comp C-4 2% of Charge Wt.	BAR. PRES.	30.17
TEST NUMBER	15-6-02 B_2	WIND DIR.	195°
CONTRACT NO.	NAS8-27750	WIND VEL.	8 Knots



FIELD EVALUATION

Complete reaction. No unburned propellant found. Will utilize 1 pound booster for the remainder of the tests. This choice was made based upon the witness plate rather than peak pressure.

Crater dimension 0.32 meter deep by 2.4 meters wide.

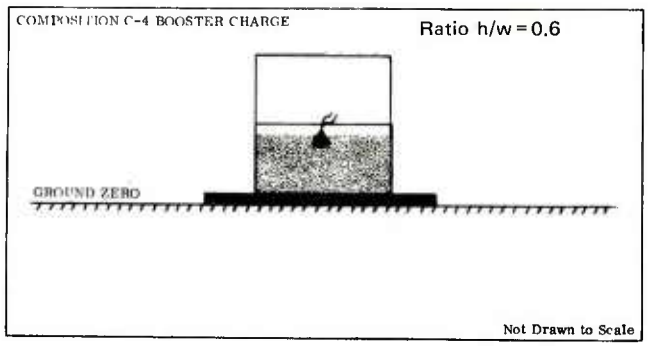
Box orientation North and South

B_2 Test 22.68 kg M10 Propellant

Channel No.	Distance Meters (ft.)	Peak Pressure kPa (psig)	Scaled Positive Impulse kPa.msec/kg$^{1/3}$ (psi. msec/lbs$^{1/3}$)	Time of Arrival (msec)	Remarks
1	3.37 (11.05)	1241.1 (180)	454.2 (50.61)	1.3	Ringing
7		1034.2 (150)	396.6 (44.20)	1.35	
2	4.55 (14.92)	620.5 (90)	219.5 (32.48)	2.2	
8		648.1 (94)	197.5 (22.01)	2.3	
3	6.04 (19.82)	248.2 (36)	154.3 (17.19)	4.0	
9		413.7 (60)	141.4 (15.76)	3.95	
4	10.11 (33.16)	68.9 (10)	57.6 (6.42)	10.4	
10		79.3 (11.5)	59.9 (6.68)	10.0	
5	20.21 (66.31)	20.7 (3.0)	35.3 (3.93)	37.6	Double peak
11		19.3 (2.8)	34.5 (3.84)	37.65	Double peak
6	44.92 (147.36)	10.3 1.5	18.6 (2.07)	106.5	Double peak
12		6.9 (1.0)	14.0 (1.56)	106.3	Double peak

Test Number 15-6-02 B3

TEST TITLE	Explosive Equivalency Testing	DATE	4/10/76
TEST SAMPLE	M10 Propellant; M-17 Shipping Container	TIME	1250 Hrs.
SAMPLE WEIGHT	50 lbs/22.68 kg	TEMP.	76°F/24.4°C
IGNITION SOURCE	J-2 Engineer's Special Blasting Cap	HUMIDITY	27%
BOOSTER WT.	1 lb/.45 kg, Comp C-4, 2% of Charge Wt.	BAR. PRES.	30.16
TEST NUMBER	15-6-02 B3	WIND DIR.	185°
CONTRACT NO.	NAS8-27750	WIND VEL.	8 Knots



FIELD EVALUATION

Complete reaction. No unburned propellant was found.

Crater dimension 0.31 meters deep by 2.4 meters wide.

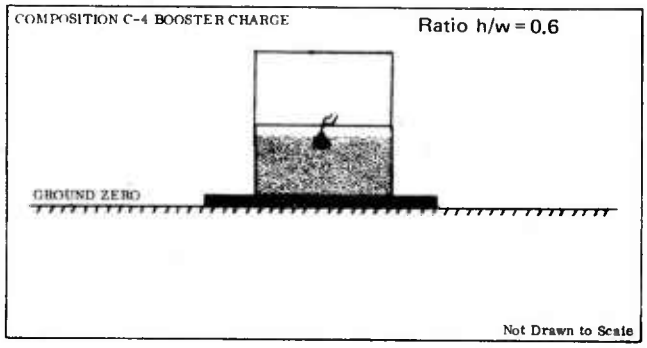
Box orientation North and South

B_3 Test 22.68 kg M10 Propellant

Channel No.	Distance Meters (ft.)	Peak Pressure kPa (psig)	Scaled Positive Impulse kPa.msec/kg$^{1/3}$ (psi. msec/lbs$^{1/3}$)	Time of Arrival (msec)	Remarks
1	3.37 (11.05)	1241.1 (180)	514.7 (57.36)	1.3	Ringing
7		965.3 (140)	469.5 (52.32)	1.2	Limited
2	4.55 (14.92)	496.4 (72)	314.0 (34.99)	2.2	
8		661.9 (96)	279.8 (31.18)	2.2	
3	8.04 (19.82)	268.9 (39)	129.1 (14.39)	3.7	
9		441.3 (64)	123.5 (13.76)	3.7	
4	10.11 (33.16)	75.8 (11)	66.0 (7.35)	10.2	
10		79.3 (11.5)	58.1 (6.47)	10.2	
5	20.21 (66.31)	- -	- -	37.4	Limited ringing
11		19.3 (2.8)	32.5 (3.62)	37.4	Double peak
6	44.92 (147.36)	10.3 (1.5)	22.6 (2.52)	106.5	Double peak
12		6.9 (1.0)	17.1 (1.91)	105.5	Double peak

Test Number 15-6-02 B4

TEST TITLE	Explosive Equivalency Testing	DATE	4/10/76
TEST SAMPLE	M10 Propellant; M-17 Shipping Container	TIME	1130 Hrs.
SAMPLE WEIGHT	50 lbs/22.68 kg	TEMP.	77°F/25°C
IGNITION SOURCE	J-2 Engineer's Special Blasting Cap	HUMIDITY	28%
BOOSTER WT.	1 lb/.45 kg, Comp C-4, 2% of Charge Wt.	BAR. PRES.	30.15
TEST NUMBER	15-6-02 B_4	WIND DIR.	180°
CONTRACT NO.	NAS8-27750	WIND VEL.	11 Knote



FIELD EVALUATION

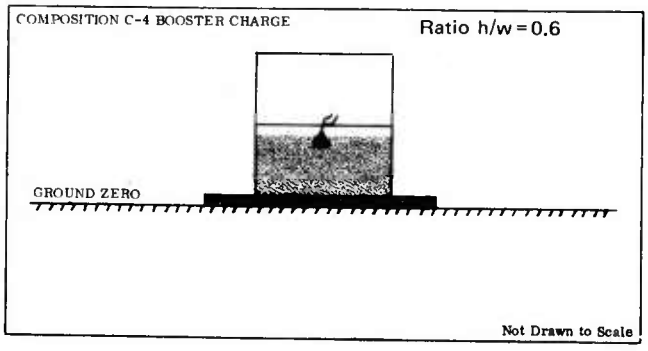
Complete reaction. No unburned propellant was found.
Crater dimension 0.31 meter deep by 2.46 meter wide.
Box orientation North and South.

B_4 Teet 22.68 kg M10 Propellent

Channel No.	Distance Meters (ft.)	Peak Pressure kPa (psig)	Scaled Positive impulse kPa.msec/kg$^{1/3}$ (psi. msec/lbs$^{1/3}$)	Time of Arrival (msec)	Remarks
1	3.37 (11.05)	- -	- -	1.15	Ringing
7		- -	- -	1.2	Limited
2	4.65 (14.92)	628.8 (91.2)	337.0 (37.56)	1.8	
8		661.9 (96)	307.2 (34.23)	2.25	
3	6.04 (19.82)	206.6 (30)	130.9 (14.59)	3.7	
9		434.4 (83)	137.1 (15.28)	3.7	
4	10.11 (33.16)	62.7 (12)	66 (7.35)	10	
10		68.3 (9.9)	57.2 (6.37)	9.9	
5	20.21 (66.31)	- -	- -	37.25	Bad channel
11		15.9 (2.3)	35.4 (3.95)	37.4	Double peak
6	44.92 (147.36)	7.6 (1.1)	21.0 (2.34)	106.54	Double peak
12		6.2 (0.9)	15.7 (1.75)	106.4	Double peak

Test Number 16-6-01 B5

TEST TITLE	Explosive Equivalency Testing	DATE	4/12/78
TEST SAMPLE	M10 Propellant M-17 Shipping Container	TIME	1030 Hrs.
SAMPLE WEIGHT	50 lbs/22.68 kg	TEMP.	81°F/27.2°C
IGNITION SOURCE	J-2 Engineer's Special Blasting Cap	HUMIDITY	48%
BOOSTER WT.	1 lb/.45 kg Comp C-4 2% of Charge Wt.	BAR. PRES.	30.20
TEST NUMBER	16-6-01 B_5	WIND DIR.	310°
CONTRACT NO.	NAS8-27750	WIND VEL.	9 Knote



FIELD EVALUATION

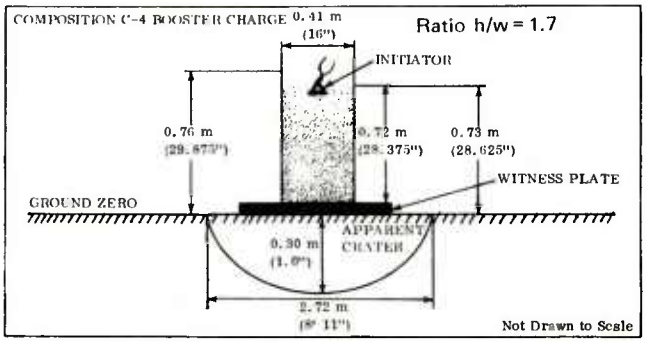
Complete detonation.
Box orientation North and South
Photographic coverage. Included Hycam 1500 (fps), Hulcher (20ppe) and documentary (24fps)
Crater dimension 0.33 meter deep by 2.21 meter wide.

B_5 Test 22.68 kg M10 Propellant

Channel No.	Distance Meters (ft.)	Peak Pressure kPa (psig)	Scaled Positive impulse kPa.msec/kg$^{1/3}$ (psi. msec/lbs$^{1/3}$)	Time of Arrival (msec)	Remarks
1	- 3.37 (11.05)	- -	-	1.2	Ringing. Bad data.
7		758.4 (110)	567.2 (63.21)	1.3	Limited
2	4.55 (14.92)	537.8 (78)	401.1 (44.70)	2.05	Double peak
8		648.1 (84)	247.5 (27.58)	2.1	Double peak
3	8.04 (18.82)	- -	- -	3.75	(Hit 3) Bad signal
9		393 (57)	155.4 (17.32)	3.7	Double peak
4	10.11 (33.16)	81.4 (11.8)	57.3 (6.39)	10.2	
10		60.7 (11.7)	53.8 (5.99)	10.4	
5	20.21 (68.31)	17.2 (2.5)	33.5 (3.73)	37.25	Double peak
11		20.7 (3.0)	38.0 (4.35)	37.7	Double peak
6	44.92 (147.36)	8.8 (1.0)	17.2 (1.92)	105.7	Double peak
12		5.5 (0.8)	12.5 (1.39)	106.4	

Test Number 16-6-02 C1

TEST TITLE	Explosive Equivalency Testing	DATE	4/13/76
TEST SAMPLE	M10 Propellant; M-24 Shipping Container	TIME	1245 Hrs.
SAMPLE WEIGHT	145 lbs/65.77 kg	TEMP.	82°F/27.8°C
IGNITION SOURCE	J-2 Engineer's Special Blasting Cap	HUMIDITY	49%
BOOSTER WT.	1.5 lbs/6.68 kg; Comp C-4 1% of Charge Wt.	BAR. PRES.	30.12
TEST NUMBER	16-6-02 C_1	WIND DIR.	160°
CONTRACT NO.	NAS8-27750	WIND VEL.	7 Knots



FIELD EVALUATION

Box orintation North and South

Complete detonation

Photographic coverage included Hycam (1500 fps) Hulcher (20pps) documentary (24fps)

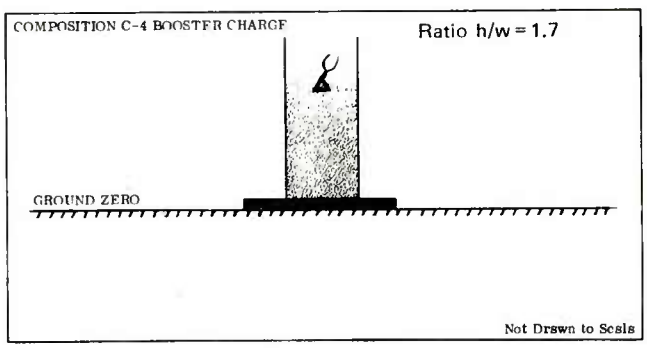
Crater dimension 0.30 meter deep by 2.72 meter wide

C_1 Test 65.77 kg M10 Propellant

Channel No.	Distance Meters (ft.)	Peak Pressure kPa (psig)	Scaled Positive Impulse kPa.msec/$kg^{1/3}$ (psi.msec/$lbs^{1/3}$)	Time of Arrival (msec)	Remarks
1	4.8 (15.76)	- -	- -	1.6	Transducer was destroyed
7		689.5 (100)	370.6 (41.30)	1.8	
2	6.49 (21.28)	579.2 (84)	304.7 (33.96)	2.5	
8		488.1 (70.8)	401.5 (44.74)	2.8	
3	8.77 (28.76)	200.8 (30)	- -	3.8	Peak failed to return to baseline
9		446.8 (64.8)	170.0 (18.95)	5.0	
4	14.41 (47.28)	106.2 (15.4)	92.8 (10.34)	12.0	
10		75.8 (11)	56.7 (6.32)	15.4	
5	28.82 (94.56)	20.0 (2.9)	21.5 (2.4)	48.55	
11		22.1 (3.2)	30.6 (3.41)	51.9	
6	64.05 (210.14)	7.9 (1.15)	14.0 (1.56)	145.25	
12		8.6 (1.25)	7.6 (0.85)	149.15	

Test Number 16-6-02 C2

TEST TITLE	Explosive Equivalency Testing	DATE	4/13/76
TEST SAMPLE	M10 Propellants M-24 Shipping Container	TIME	1445 Hrs.
SAMPLE WEIGHT	145 lbs/65.77 kg	TEMP.	78°F/25.6°C
IGNITION SOURCE	J-2 Engineer's Special Blasting Cap	HUMIDITY	56%
BOOSTER WT.	2.5 lbs./1.13 kg Comp C-4 1.5 % of Charge Wt.	BAR. PRES.	30.11
TEST NUMBER	16-6-02 C_2	WIND DIR.	195°
CONTRACT NO.	NAS8-27750	WIND VEL.	9 Knots



FIELD EVALUATION

Box orisntation North and South

Crater dimension 0.33 meters deep by 2.72 meters wide

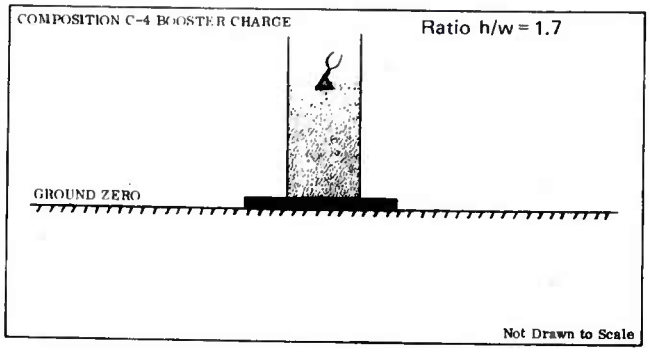
C_2 Test 65.77 kg M10 Propellant

Channel No.	Distance Meters (ft.)	Peak Pressure kPa (psig)	Scaled Positive Impulse kPa.msec/$kg^{1/3}$ (psi.msec/$lbs^{1/3}$)	Time of Arrival (msec)	Remarks
1	4.8 (15.76)	1379.0 (200)	317.8 (35.42)	1.7	
7		772.2 (112)	236.0 (26.30)	1.9	
2	6.49 (21.28)	537.8 (78)	389.0 (43.35)	2.7	
8		620.5 (90)	374.4 (41.72)	3.0	
3	8.77 (28.70)	268.9 (39)	148.6 (16.56)	4.5	
9		455.1 (66)	139.9 (15.59)	5.2	
4	14.41 (47.28)	106.2 (15.4)	79.9 (8.9)	14.0	
10		77.2 (11.2)	47.0 (5.24)	15.7	
5	28.82 (64.56)	22.8 (3.3)	23.7 (2.64)	49.7	
11		22.1 (3.2)	33.1 (3.69)	52.4	
6	64.05 (210.14)	10.3 (1.5)	4.8 (0.54)	147.4	
12		10.3 (1.5)	9.2 (1.02)	150	

Test Number 16-6-02 C3

TEST TITLE: Explosive Equivalsncy Testing
TEST SAMPLE: M10 Propellant; M-24 Shipping Container
SAMPLE WEIGHT: 145 lbs/65.77 kg
IGNITION SOURCE: J-2 Engineer's Special Blasting Cap
BOOSTER WT.: 1.5 lbs/.68 kg Comp C-4; 1% of Charge Wt.
TEST NUMBER: 16-6-02 C_3
CONTRACT NO.: NAS8-27750

DATE: 4/14/76
TIME: 1300 Hrs.
TEMP.: 82°F/27.8°C
HUMIDITY: 52%
BAR. PRES.: 30.13
WIND DIR.: 150°
WIND VEL.: 13 Knots



FIELD EVALUATION
Box orientation North and South
Crater dimension 0.41 meters deep by 3.05 meters wide

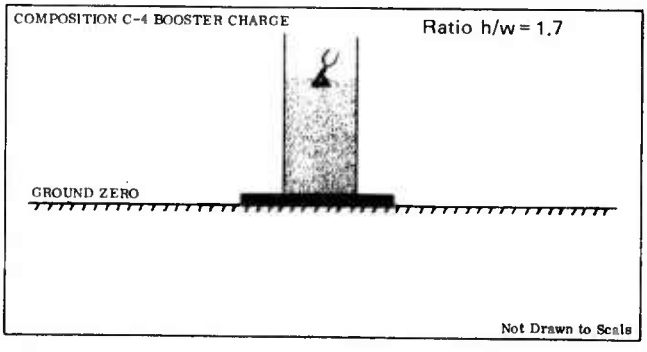
C_3 Test 85.77 kg M10 Propellant

Channel No.	Distance Meters (ft.)	Peak Pressure kPa (psig)	Scaled Positive Impulse $kPa.msec/kg^{1/3}$ ($psi.msec/lbs^{1/3}$)	Time of Arrival (msec)	Remarks
1	4.8 (15.76)	- -	- -	1.6	Txder destroyed.
7		965.3 (140)	556.8 (62.05)	1.9	
2	8.49 (21.28)	524 (76)	436.6 (43.68)	2.1	
8		510.2 (74)	355.2 (39.58)	3.2	
3	8.77 (28.76)	228.9 (33.2)	243.0 (27.08)	3.6	
9		289.6 (42)	765.0 (18.39)	5.3	
4	14.41 (47.28)	96.5 (14)	50.3 (5.60)	12.1	
10		74.5 (10.8)	58.1 (6.46)	15.6	
5	28.82 (94.56)	20.7 (3)	18.5 (2.06)	48.6	
11		20.7 (3)	31.2 (3.48)	53.2	
6	84.05 (210.14)	6.2 (0.9)	15.1 (1.68)	145.9	
12		8.3 (1.2)	8.6 (0.98)	149.8	

Test Number 16-6-02 C4

TEST TITLE: Explosive Equivalency Testing
TEST SAMPLE: M10 Propellant; M-24 Shipping Container
SAMPLE WEIGHT: 145 lbs/65.77 kg
IGNITION SOURCE: J-2 Engineer's Special Blasting Cap
BOOSTER WT.: 1.5 lbs/0.68 kg; Comp C-4; 1% of Charge Wt.
TEST NUMBER: 16-6-02 C_4
CONTRACT NO.: NAS8-27750

DATE: 4/14/76
TIME: 1405 Hrs.
TEMP.: 80°F/26.7°C
HUMIDITY: 54%
BAR. PRES.: 30.11
WIND DIR.: 150°
WIND VEL.: 11 Knots



FIELD EVALUATION
Box orientation North and South
Crater dimension 0.46 meters deep by 3.56 meters wide

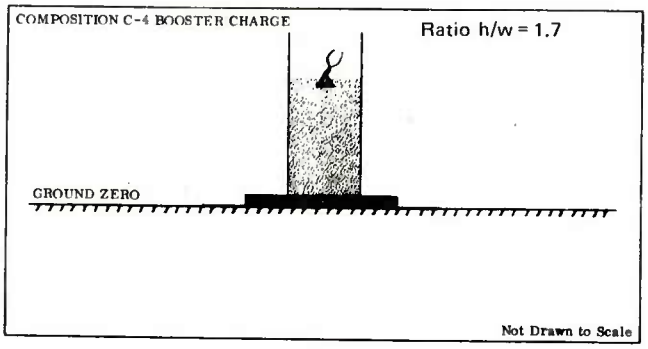
C_4 Tsst 65.77 kg M10 Propellant

Channel No.	Distance Meters (ft.)	Peak Pressure kPa (psig)	Scaled Positive Impulse $kPa.msec/kg^{1/3}$ ($psi.msec/lbs^{1/3}$)	Time of Arrival (msec)	Remarks
1	4.8 (15.76)	- -	- -	1.6	Csble damage.
7		965.3 (140)	333.4 (37.15)	1.8	
2	8.49 (21.28)	519.2 (84)	487.5 (53.44)	2.3	
8		827.4 (120)	345.3 (36.48)	3.1	
3	8.77 (28.78)	289.8 (42)	145.5 16.21	4.6	
9		386.1 (56)	170.7 (19.02)	5.4	
4	14.41 (47.28)	98.5 (14)	76.3 (8.50)	13.2	
10		82.7 (12)	71.5 (7.97)	15.6	
5	28.82 94.56	21.4 (3.1)	28.5 (2.95)	48.8	
11		20.7 (3)	32.8 (3.65)	51.1	
6	64.05 (210.14)	8.2 (0.9)	14.7 (1.64)	146.5	
12		9.0 (1.3)	11.8 (1.32)	148.5	

Test Number 16-6-02 C5

TEST TITLE	Explosive Equivalency
TEST SAMPLE	M10 Propellant; M-24 Shipping Container
SAMPLE WEIGHT	145 lbs/65.77 kg
IGNITION SOURCE	J-2 Engineer's Special Blasting Cap
BOOSTER WT.	1.5 lbs/0.68 kg Comp C-4 1% of Charge Wt.
TEST NUMBER	18-6-02 C_5
CONTRACT NO.	NAS8-27750

DATE	4/15/78
TIME	1301 Hrs.
TEMP.	81°F/27.2°C
HUMIDITY	51%
BAR. PRES.	30.11
WIND DIR.	105°
WIND VEL.	14 Knots



FIELD EVALUATION

Box orientation North and South

Crater dimension 0.37 meters deep by 3.01 meters wide

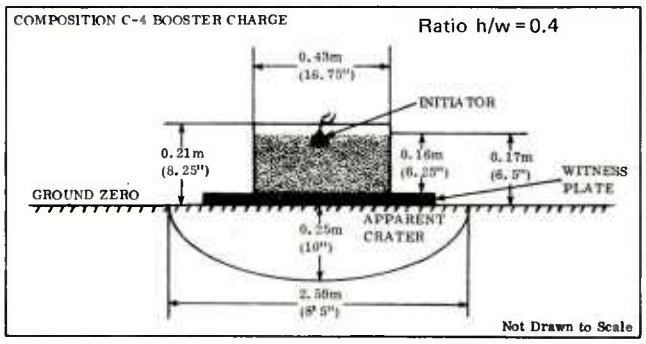
C_5 Test 65.77 kg M10 Propellant

Channel No.	Distance Meters (ft.)	Peak Pressure kPa (psig)	Scaled Positive Impulse kPa.msec/kg$^{1/3}$ (psi. msec/lbs$^{1/3}$)	Time of Arrival (msec)	Remarks
1	4.8 (15.76)	- -	- -	1.6	Hit? ?
7		1034.2 (150)	-	2.0	Failed to return to baseline
2	6.49 (21.28)	- -	- -	2.5	Transducer damaged
8		758.4 (110)	88.5 (9.86)	3.0	
3	8.77 (28.78)	- -		3.8	Missed data
9		889.4 (129)	189.6 (21.13)	5.0	
4	14.41 (47.28)	75.8 (11)	65.3 (7.28)	12.2	
10		- -	- -	-	No data
5	28.82 (94.56)	20.7 (3)	30.9 (3.44)	48.1	
11		20 (2.9)	34.5 (3.85)	52.7	
6	64.05 (210.14)	12.4 (1.8)	14.9 (1.66)	145.2	
12		10.3 (1.5)	11.4 (1.27)	150.2	

Test Number 17-7-01 D1

TEST TITLE	Explosive Equivalency Testing
TEST SAMPLE	M10 Propellant Scaled Shipping Container
SAMPLE WEIGHT	25 lbs/11.34 kg
IGNITION SOURCE	J-2 Engineer's Blasting Cap
BOOSTER WT.	0.25 lbs/0.11 kg Comp C-4 1% of Charge Wt.
TEST NUMBER	17-7-01 D_1
CONTRACT NO.	NAS8-27750

DATE	4/19/76
TIME	1257 Hrs.
TEMP.	81°F/27.2°C
HUMIDITY	53%
BAR. PRES.	30.08
WIND DIR.	190°
WIND VEL.	10 Knots



FIELD EVALUATION

Photographic coverage included Hycam (1500 fps) Hulchen (20pps) documentation (24fps)

Complete detonation. No visible signs of unburned propellant

Crater dimension 0.25 meter deep by 2.59 meters wide

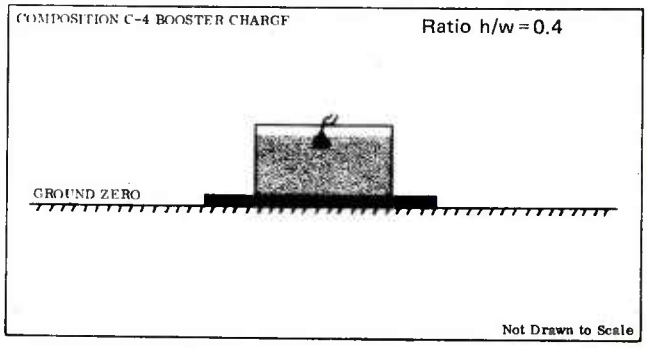
Box orientation long side North and South.

D_1 Test 11.34 kg (25 lb) M10 Propellant

Channel No.	Distance Meters (ft.)	Peak Pressure kPa (psig)	Scaled Positive Impulse kPa.msec/kg$^{1/3}$ (psi. msec/lbs$^{1/3}$)	Time of Arrival (msec)	Remarks
1	2.87 (8.77)	1241.1 (180)	745.1 (83.024)	0.95	
7		1172.1 (170)	475.6 (53.0)	1.0	
2	3.61 (11.84)	620.5 (90)	331.03 (36.89)	1.8	
8		661.9 (98)	350.8 (39.01)	1.8	
3	4.80 (15.70)	227.5 (33)	149.7 (16.68)	3.25	
9		262.0 (38)	188.9 (21.05)	3.4	
4	8.02 (26.52)	79.3 (11.5)	71.7 (7.99)	9.4	
10		67.6 (9.8)	46.4 (5.17)	10.2	
5	18.04 (52.83)	22.8 (3.3)	26.1 (2.91)	29.45	
11		18.3 (2.8)	35.12 (3.91)	31.0	
8	35.7 (116.86)	6.2 (0.8)	19.6 (2.18)	83.2	
12		8.9 (1.0)	18.21 (2.03)	85.8	

Test Number 17-6-01 D4

TEST TITLE	Explosive Equivalency Testing	DATE	4/20/76
TEST SAMPLE	M10 Propellant; Scaled Shipping Container	TIME	1227 Hrs.
SAMPLE WEIGHT	25 lbs/11.34 kg	TEMP.	79°F/26.1°C
IGNITION SOURCE	J-2 Engineer's Special Blasting Cap	HUMIDITY	64%
BOOSTER WT.	0.5 lbs/0.23 kg, Comp C-4, 2% of Charge Wt.	BAR. PRES.	29.93
TEST NUMBER	17-6-01 D_4	WIND DIR.	190°
CONTRACT NO.	NAS8-27750	WIND VEL.	11 Knots



FIELD EVALUATION

Box orientation North and South

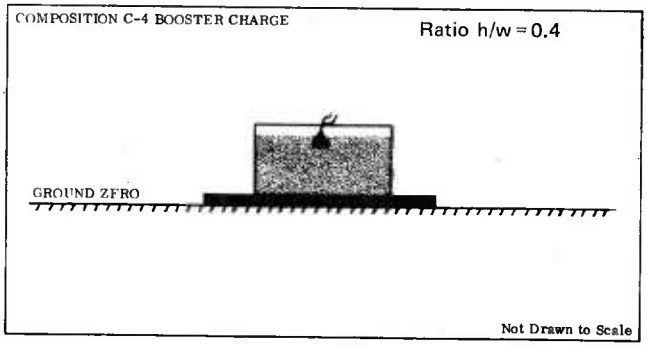
Crater dimension 0.27 meters deep by 2.97 meters wide

D_4 Test 11.34 kg (25 lb) M10 Propellant

Channel No.	Distance Meters (ft.)	Peak Pressure kPa (psig)	Scaled Positive Impulse $kPa.msec/kg^{1/3}$ ($psi.msec/lbs^{1/3}$)	Time of Arrival (msec)	Remarks
1	2.67 (8.77)	1172.1 (170)	591.8 (65.95)	1.15	
7		1241.1 (180)	878.7 (97.92)	1.0	
2	3.61 (11.84)	289.6 (42)	296.4 (33.03)	1.9	
8		537.8 (78)	335.1 (37.34)	1.6	
3	4.8 (15.70)	220.6 (32)	134.4 (14.98)	3.4	
9		386.1 (56)	148.3 (16.52)	2.75	
4	8.02 (26.32)	75.8 (11.0)	66.0 (7.35)	9.0	
10		41.4 (6.0)	42.9 (4.78)	8.8	
5	16.04 (52.63)	17.9 (2.6)	34.7 (3.86)	29.3	
11		16.2 (2.35)	36.5 (4.07)	29.7	
6	35.7 (116.96)	6.2 (0.9)	17.1 (1.91)	83.3	
12		6.9 (1.0)	16.2 (1.81)	84.1	

Test Number 17-6-01 D5

TEST TITLE	Explosive Equivalency Testing	DATE	4/20/76
TEST SAMPLE	M10 Propellant; Scaled Shipping Container	TIME	1300 Hrs.
SAMPLE WEIGHT	25 lbs/11.34 kg	TEMP.	83°F/28.3°C
IGNITION SOURCE	J-2 Engineer's Special Blasting Cap	HUMIDITY	63%
BOOSTER WT.	.5 lbs/.23 kg, Comp C-4 2% of Charge Wt.	BAR. PRES.	29.93
TEST NUMBER	17-6-01 D_5	WIND DIR.	180°
CONTRACT NO.	NAS8-27750	WIND VEL.	6 Knots



FIELD EVALUATION

Box orientation North and South

Crater dimension 0.30 meters deep by 2.95 meters wide

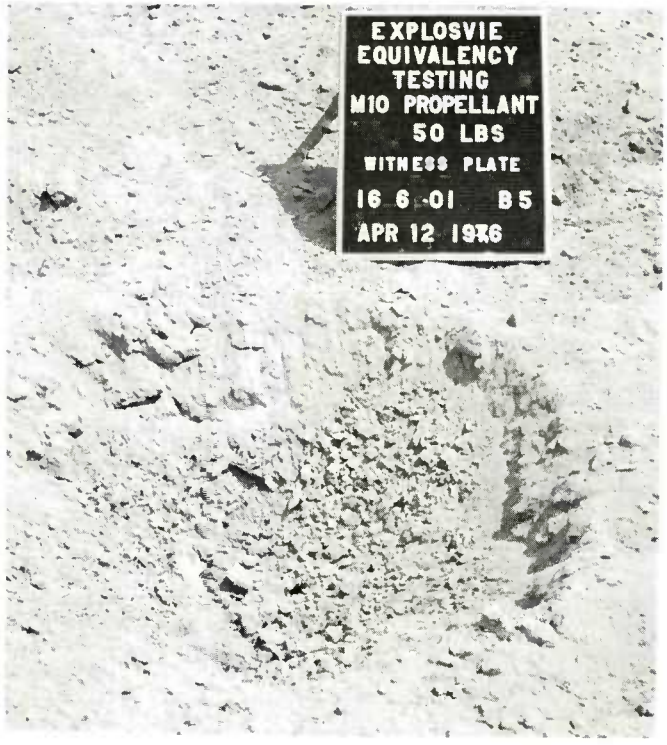
D_5 Test 11.34 kg (25 lb) M10 Propellant

Channel No.	Distance Meters (ft.)	Peak Pressure kPa (psig)	Scaled Positive Impulse $kPa.msec/kg^{1/3}$ ($psi.msec/lbs^{1/3}$)	Time of Arrival (msec)	Remarks
1	2.67 (8.77)	1241.1 (180)	619.3 (89.01)	1.1	
7		1241.1 (180)	551.9 (61.40)	0.9	
2	3.61 (11.84)	482.6 (70)	327.8 (38.53)	1.8	
8		806.7 (117)	390.2 (43.48)	1.65	
3	4.8 (15.7)	248.2 (36)	135.9 (15.15)	3.2	
9		317.2 (46)	169.7 (18.91)	3.2	
4	8.02 (26.32)	86.2 (12.5	64.5 (7.19)	8.7	
10		62.1 (9.0)	49.5 (5.52)	9.4	
5	16.04 (52.63)	20.7 (3.0)	36.3 (4.04)	28.9	
11		17.9 (2.6)	39.0 (4.35)	30.1	
6	35.7 (116.96)	6.2 (0.9)	19.6 (2.19)	83.2	
12		6.9 (1.0)	18.6 (1.85)	84.8	

APPENDIX B

SELECTED PHOTOGRAPHS

PRETEST CONFIGURATION 22.68 kg CHARGE



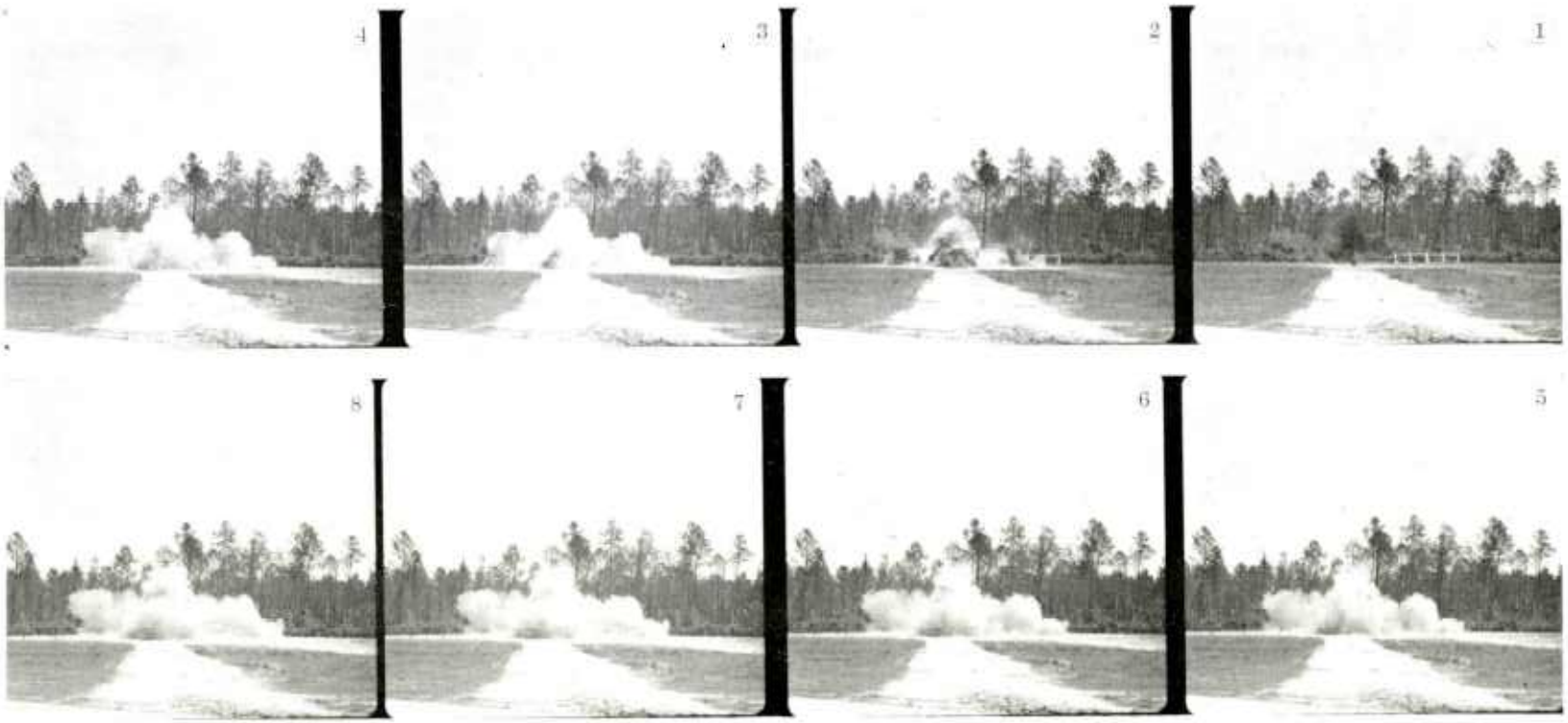
POST TEST CRATER 22.68 kg CHARGE

PRETEST CONFIGURATION 45.4 kg CHARGE

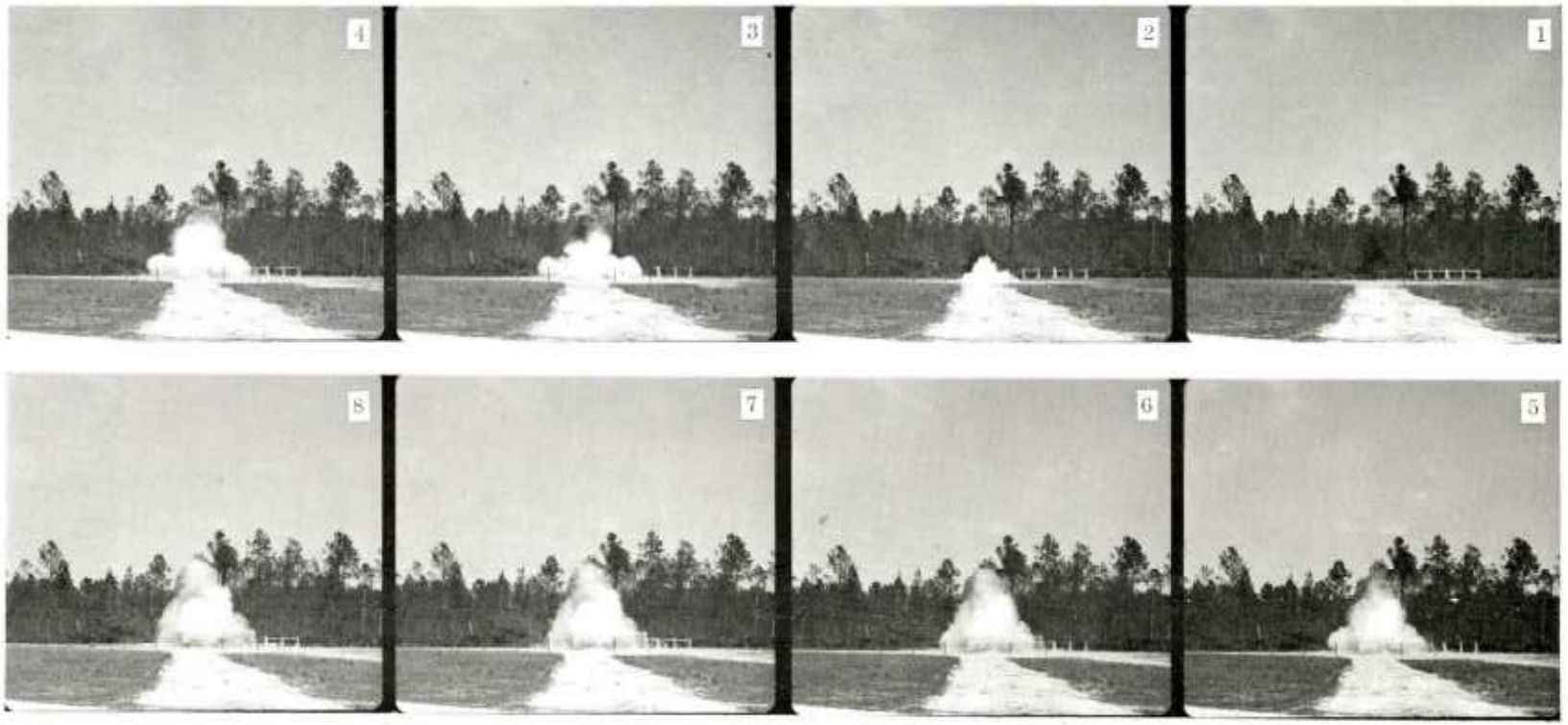
POST TEST CRATER AND WITNESS PLATE

PRETEST CONFIGURATION 65.8 kg CHARGE

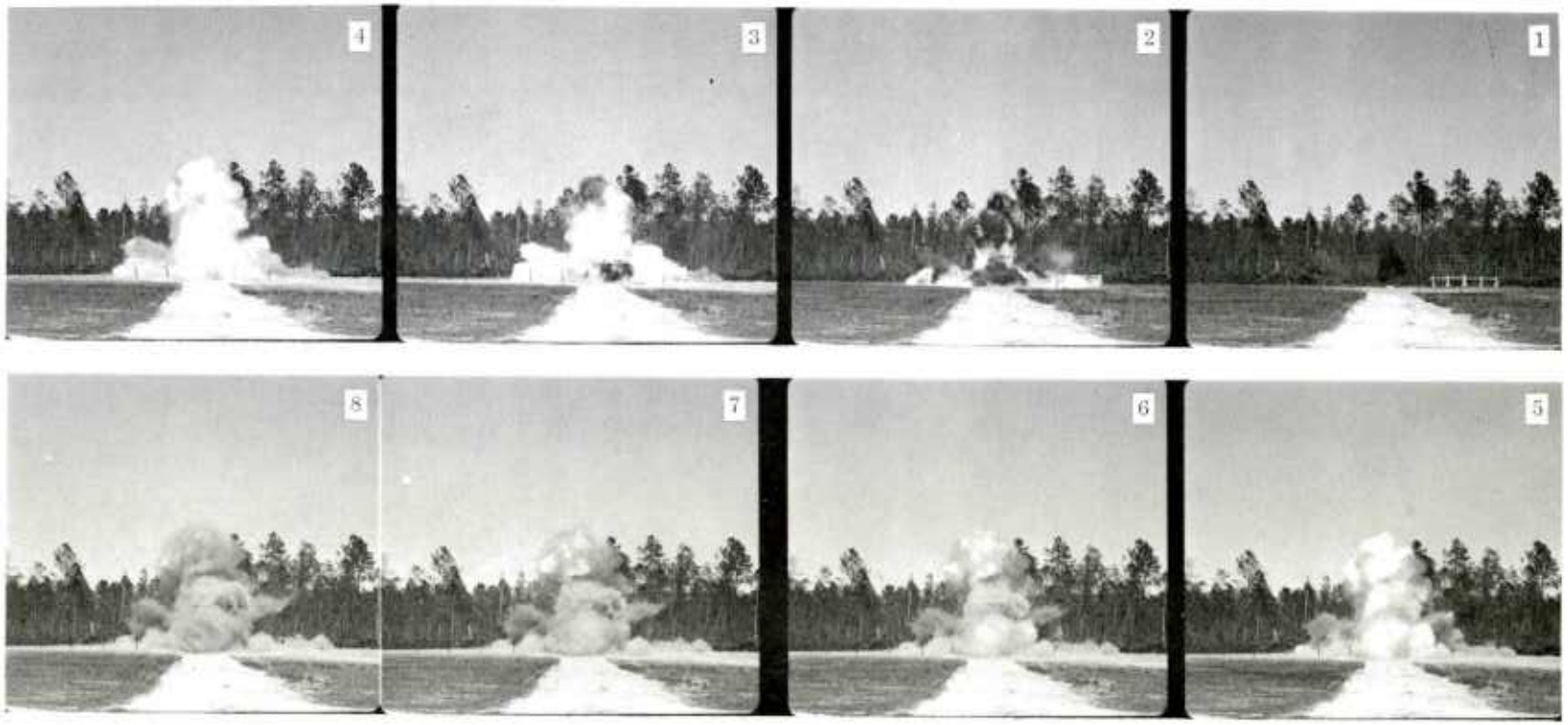
POST TEST CRATER 65.8 kg CHARGE



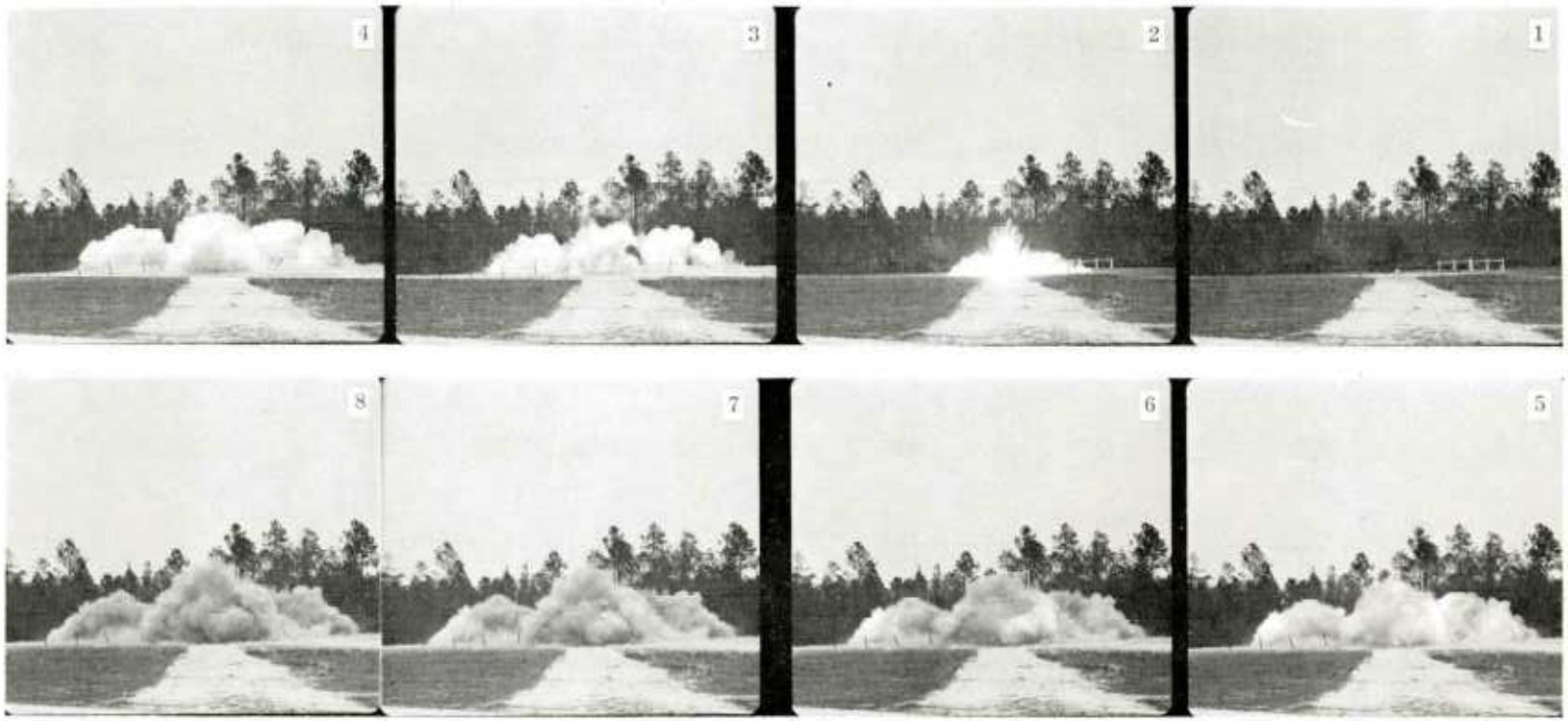
Fireball Characteristics from Hulcher Model 40
Sequencing Camera (Frame Rate 50 ms/frame)
22.68 kg Charge Weight



Fireball Characteristics from Hulcher Model 40
Sequencing Camera (Frame Rate 50 ms/frame)
11.34 kg Charge Weight



Fireball Characteristics from Hulcher Model 40
Sequencing Camera (Frame Rate 50 ms/frame)
45.4 kg Charge Weight



Fireball Characteristics from Hulcher Model 40
Sequencing Camera (Frame Rate 50 ms/frame)
65.8 kg Charge Weight

APPENDIX C

SAFETY APPROVAL

Mr. Khwaja/cs/5441

DRSAR-IRC-E (2 Jun 77) 1st Ind
SUBJECT: Preliminary Report, TNT Equivalency Test of M10 Propellant

HQ, US Army Armament Materiel Readiness Command, Rock Island, IL 61299

2 NOV 1977

TO: Commander, US Army Armament Research and Development Command,
ATTN: DRDAR-LCM-SP, Dover, NJ 07801

1. Subject draft report on TNT Equivalency Test of M10 Propellant was reviewed and is approved by HQ, ARRCOM including DRSAR-SF and HQ, DARCOM, DRCSF-E.

2. Request ARRADCOM proceed with the final publication of the report.

FOR THE COMMANDER:

George H. Cowan

GEORGE H. COWAN
Chief, Chemical
Technology Division

wd all incl

CF:
PM, MPBME
(DRCPM-PBM-T-SF/
DRCPM-PBM-LA/DRCPM-PBM-LN2)
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